Climate change, perceived human environment changes, and adaptation responses in coastal Indigenous community of Akplabanya, Ghana

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Abstract

Coastal communities are facing unprecedented challenges as impacts of climate change continue to escalate globally. Rising sea levels, intensified storm activity, and coastal erosion are extreme climate impacts noticed frequently in coastal communities. Indigenous coastal communities in Ghana are impacted by these extreme climate impacts. In this thesis, I studied the perceived human-environment changes in Indigenous community of Akplabanya. Akplabanya community on the coast of Ghana is experiencing changes in their cultural heritage, environmental surroundings, and their climate. This thesis sought to explore adaptation dynamics within Akplabanya and offer insights into their human-environmental changes and resilience in the face of climate change. In studies that focus on Ghana, little is known about the changes of human-environment interaction in Akplabanya, or their Indigenous peoples' responses to those changes. The two objectives of this study are: 1). To identify changes in coastal human-environment interactions as perceived by the Akplabanya Indigenous community, and 2). To examine the human adaptation responses of the Akplabanya community to the changes in their coastal human-environment interactions. I used four qualitative data collection methods. Semi-structured interviews (n=61) enlisted personal experiences and insights on changing environment and adaptation responses. Key informant interviews (n=28) provided additional insights into context and history. Focused group discussions (n=3), each comprising five participants, focused the community's collective narratives on changing environment and adaptation responses. Participant observation conducted throughout data collection helped me to understand daily life of Akplabanya. Data collection occurred over a period of two months (December 2022-February 2023). I found five themes to explain Akplabanya's perceptions about the changes of coastal human-environment interactions. They are: 1). Biodiversity loss (e.g. vegetation loss), 2). Pollution (e.g. unsustainable practices), 3). Coastal climate change (e.g. coastal erosion), 4). Resource change (e.g. freshwater change), and Population change (e.g. increasing population). I also built participant responses that addressed objective 2 on themes of place, agency, collective action, institutions, coastal Indigenous knowledge, and learning. The findings built on these themes highlights changes in coastal human-environment interactions in coastal fisheries, water systems, land utilization, livestock management, architectural practices, and the preservation of Indigenous knowledge in Akplabanya.

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General Audience Abstract

Coastal communities are facing unprecedented challenges as impacts of climate change continue to escalate globally. Rising sea levels, intensified storm activity, and coastal erosion are extreme climate impacts noticed frequently in coastal communities. Indigenous coastal communities in Ghana are impacted by these extreme climate impacts. In this thesis, I studied the perceived human-environment changes in Indigenous community of Akplabanya. Akplabanya community on the coast of Ghana, is experiencing changes in their cultural heritage, environmental surroundings, and their climate. This thesis sought to explore adaptation dynamics within Akplabanya and offer insights into their human-environmental changes and resilience in the face of climate change. In studies that focus on Ghana, little is known about the changes of human-environment interaction in Akplabanya, or their Indigenous peoples' responses to those changes. The two objectives of this study are: 1). To identify changes in coastal human-environment interactions as perceived by the Akplabanya Indigenous community, and 2). To examine the human adaptation responses of the Akplabanya community to the changes in their coastal human-environment interactions. I used four qualitative data collection methods. Semi-structured interviews (n=61) enlisted personal experiences and insights on changing environment and adaptation responses. Key informant interviews (n=28) provided additional insights into context and history. Focused group discussions (n=3), each comprising five participants, focused the community's collective narratives on changing environment and adaptation responses. Participant observation conducted throughout data collection helped me to understand daily life of Akplabanya. Data collection occurred over a period of two months (December 2022-February 2023). I found five themes to explain Akplabanya's perceptions about the changes of coastal human-environment interactions. They are: 1). Biodiversity loss (e.g. vegetation loss), 2). Pollution (e.g. unsustainable practices), 3). Coastal climate change (e.g. coastal erosion), 4). Resource change (e.g. freshwater change), and Population change (e.g. increasing population). I also built participant responses that addressed objective 2 on themes of place, agency, collective action, institutions, coastal Indigenous knowledge, and learning. The findings built on these themes highlights changes in coastal human-environment interactions in coastal fisheries, water systems, land utilization, livestock management, architectural practices, and the preservation of Indigenous knowledge in Akplabanya.

Dedication

This project is dedicated to Indigenous community of Akplabanya, Ada West, Ghana, who are constantly changing their way of life to fit their changing environment.

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Preface/ attribution

This thesis includes a manuscript that is being prepared for submission to a peer-reviewed journal.

The manuscript titled "Perceived social-ecological changes and adaptive responses in coastal Indigenous community of Akplabanya, Ghana" and listed under Chapter 2. The author's contributions to the manuscript are as follows.

Brandy Ayesu-Danso conducted the field data collection in Akplabanya, Ghana, data analysis, as manuscript writing, and incorporated feedback from Eranga Galappaththi.

Eranga Galappaththi contributed to the conceptual development of the manuscript, providing comments, feedback, and suggestions. Anamaria Bukvic, Santosh Rijal and Timothy Baird further reviewed the entire thesis and provided comments.

Table of contents

List of figures

List of tables

Chapter 1: Introduction

1.1 Background and Problem Statement

The continual adverse change of climate has become of global concern. Climate change and its adverse impacts are affecting all aspects of human society, especially the environment, social and economic systems on earth. According to Makowski & Finkl (2018), climate change adversely influences frequencies and intensities of temperature, precipitation, oceanic atmospheric circulation, and distribution of hurricanes and tropical storms. These aforementioned variables together with mean sea level, wave conditions, storm surge, and river flows also influence the world's coastlines (Ranasinghe, 2016). As the Intergovernmental Panel on Climate Change (IPCC) Assessment Report Six emphasized, every region in the world is experiencing widespread, fast, and intensified changes (IPCC, 2021). The IPCC also reported that observed warming trends continue to increase at a higher rate than the projected global average with a significantly greater increase in sea-level rise (IPCC, 2021).

The way people experience climate change can vary both regionally and among different peoples. People in Least Developed Countries (LDC) like Ghana and Nigeria contribute very little to the emission of greenhouse gasses that exacerbate climate change, yet they are affected by climate change the most (Ashrafuzzaman & Furini, 2019). According to the United Nations' Trade and Development report on Least Developed Countries (2023) approximately 1.1 billion people living in LDC, have contributed less than 4% of the world's total greenhouse gas emissions. However, LCD have suffered disproportionately from the consequences of climate-related disasters. Over the past 50 years, LDC accounted for 69% of global deaths resulting from climate-related disasters (United Nations, 2023). LDC faces unique challenges due to their reliance on commodity exports which is often linked to high CO_2 emissions, their vulnerability to global food market fluctuations and external crises such as the COVID-19 pandemic and the war in Ukraine (United Nations, 2023). Similarly, Ospina et al. (2012) reported that climate change impacts such as decreasing fish stocks, high coastal erosion, and severe flooding in Ghana led to increased poverty and inadequate infrastructure within coastal Indigenous communities.

Indigenous coastal communities in Ghana, such as Akplabanya (Figure 1.1 & Figure 1.2), face significant vulnerability to the impacts of climate change, including issues like sea-level rise, coastal erosion, and flooding, as highlighted in various studies (Cudjoe & Kwabla Alorvor, 2021;

Nyadzi et al., 2020; Yankson et al., 2017). Research by Addo (2021) revealed that a substantial portion of Ghana's eastern coastal land experienced erosion and flooding between 2005 and 2017, resulting in the transformation of some fishing villages into isolated islands. The Environmental Protection Agency (EPA) in Ghana has published the National Environmental Action Plan (1994), Draft Integrated Coastal Zone Plan (1998), and Coastal Zone Management Indicative Plan (1990), which outlines adaptation strategies and policies. However, the strategies documented in these reports have yet to be effectively implemented focusing on Indigenous communities. The ineffective implementation of these plans are in part due to the knowledge gap surrounding human-environment interactions that is being impacted by climate change in Indigenous communities like Akplabanya (Figure 1.1 and Figure 1.2).

Figure 1.1: Fishers and fishmongers of Akplabanya trading fish catch on the coast (Photo by Brandy).

Figure 1.2: Fishers and fishmongers of Akplabanya trading fish catch on the coast (Photo by Brandy).

1.2 Theoretical Context

Social-ecological systems approach will integrate the scholarship areas of vulnerability, climate adaptation, coping, transformation, maladaptation, the basin of attraction, and resilience to understand how members of Indigenous community of Akplabanya perceive and respond to change in human-environment interactions.

Social-ecological systems

Social-ecological systems conceptual approach to study complex adaptive systems represents a lens that emerged from the intersection of ecology, social sciences, and systems theory (Berkes, 2010; Brondizio et al., 2009). At its core, the social-ecological systems lens posits that the well-being of ecosystems and of human societies are intricately connected and evolve together over time (Berkes et al., 1998, 2003). It further underscores the interconnected relationships between human activities, governance structures, institutions, as well as external factors and internal feedback mechanisms (Westley et al., 2013; Berkes & Folke, 2000). An example of social-ecological systems is fishing villages and towns that depend on coastal and marine resources for their livelihoods. The health of fisheries, ocean ecosystems, and local fishing practices are also

integral to their fisheries system. Studying coastal Indigenous communities, through social-ecological system lens, aids researchers and policymakers to better understand and address the complex challenges posed by environmental changes, human activities, and the feedbacks of the two linked subsystems (Adger et al., 2013).

Social-ecological systems change is the sudden regime shifts and "long-term" changes with interconnected systems of people and nature with unforeseen "implications for ecosystem services and human wellbeing" (Nayak & Armitage, 2018; pg. 84). These changes can be driven by various factors, including environmental pressures, human activities, policy decisions, and external shocks. In the context of Indigenous studies, social-ecological systems changes take on particular significance and complexity. This complexity involves Indigenous knowledge systems that have been developed and passed down through generations. This Indigenous knowledge includes insights into local ecosystems, sustainable resource management, and adaptation to environmental change. As Indigenous communities often have deep connections to their environments, relying on traditional knowledge and practices for their livelihoods and cultural identities, they perceive transformations and shifts in the historical timeline of their culture and ecological dimensions.

The perceptions of Indigenous communities on transformations and shifts in their communities become their social-ecological memory. Social-ecological memory is one lens that can be used to understand the collective knowledge, experiences, and practices of Indigenous communities in relation to their interactions with ecosystems and natural resources over time (Nykvist & von Heland, 2014). Social-ecological memory can include sustainable resource management, adaptation to environmental changes, and coping strategies developed through historical experiences. It enables Indigenous communities to learn from past successes and failures, adjust their practices, and respond innovatively to evolving environmental and societal conditions (Rodríguez Valencia et al., 2019). Therefore, perceived social-ecological systems changes represent the reservoir of knowledge that Indigenous communities are developed over time in response to their environmental contexts.

Vulnerability

Vulnerability is susceptibility to harm. Vulnerability, in the context of climate change and social-ecological systems, refers to the susceptibility of individuals, communities, or ecosystems to harm or adverse impacts resulting from climate-related changes or other stressors (Adger, 2006). This is the extent to which a "system, subsystem or system component" is susceptible to harm as a result

of climate hazards or stressors (Cook & Frankel-Reed, 2016; Turner et al., 2003). Vulnerability is influenced by a combination of factors, including exposure to climate hazards, sensitivity to those hazards, and the capacity to adapt and cope with them (Smit & Wandel, 2006). Exposure is a fundamental component of vulnerability, which denotes the degree to which a system or population is likely to encounter adverse climate-related events or stressors (Antwi-Agyei et al., 2018; Westerhoff & Smit, 2009). These adverse climate-related events include extreme weather events, sea-level rise, and shifts in temperature and precipitation patterns. High exposure increases the potential for negative impacts (IPCC, 2014). Sensitivity is another critical dimension of vulnerability, which assesses how vulnerable a system is to climate-related changes and how severe the consequences may be for that system (Füssel, 2010). Systems or populations with higher sensitivity may experience more severe consequences from the same climate change impacts (Füssel & Klein, 2006).

Climate change adaptation

Climate change adaptation refers to the deliberate strategies and actions taken by individuals, communities, organizations, and governments to respond to the adverse effects of climate change (IPCC, 2014). It encompasses a wide range of measures, from adjustments in practices and technologies to policy changes and community-based initiatives (Owen, 2020; Piggott-McKellar et al., 2019). The goal of adaptation is to reduce vulnerability and enhance resilience to the impacts of climate change (Nelson, 2011). It recognizes that climate change is already occurring and anticipates future changes, emphasizing the need for proactive responses to protect human and natural systems from harm (Smit & Wandel, 2006). Therefore, adaptive responses are a set of resources in a location and the ability of the people of the location to organize and use these resources to respond or adapt to climatic stressors (Freduah et al., 2018; Nelson, 2011; Nelson et al., 2007). Responses are meant to deal with current or future predicted change or perturbations to a social-ecological system without undergoing significant changes in function, structural identity, or feedback of that system while maintaining the option to develop (Nelson et al., 2007).

Coping

Coping used in this study refers to the use of available skills, resources, and opportunities to address, manage, and overcome adverse conditions (Ford et al. 2020; Whitfield et al., 2019; Gunderson & Holling, 2002). These coping strategies draw upon traditional knowledge, emphasizing a deep understanding of local ecosystems, sustainable resource management, and

adaptation to shifting environmental conditions (Kihila, 2018; Mah et al., 2020). Indigenous communities often diversify their livelihoods, engage in collective action, adapt their governance structures, and innovate new techniques to cope with changes in social-ecological systems (Athayde & Silva-Lugo, 2018). Coping strategies are essential for enhancing the resilience of Indigenous communities as they navigate the complex challenges presented by social-ecological changes and climate-related stressors (Hooli, 2016). For instance, coping strategies that are commonly observed in Indigenous communities, such as crop diversification, water management techniques, and the preservation of cultural practices help communities adapt to changing social ecological systems.

Transformation

Transformation used in this study is a process that results in a fundamental change in systems or structures to establish a significantly altered (often more sustainable) state over a long-term period (Fawcett et al., 2017; Westley et al., 2013; Gunderson & Holling, 2002). Indigenous communities may undergo transformations in response to environmental changes, adopting new practices and structures that allow them to adapt to evolving conditions while maintaining their essential functions and identities (Folke et al., 2010; Nelson et al., 2007). Indigenous peoples, deeply connected to their communities, may undertake transformational changes in their practices, resource management, governance structures, and cultural norms to respond effectively to environmental changes and social pressures (Nelson et al., 2007). These transformations often involve a reevaluation of traditional knowledge systems, decision-making processes, and community values to better align with sustainable practices and resilient outcomes. In the face of climate-related stressors and broader social-ecological shifts, the ability of Indigenous communities to transform reflects their capacity to adapt to new realities while preserving their cultural heritage and ecological integrity (Folke, 2016).

Maladaptation

According to Barnett & O'Neill (2013, p. 88), maladaptation is defined as "actions taken to adapt to climate change that inadvertently increase the vulnerability of other systems, sectors, or social groups". In the context of social-ecological systems, Maladaptation can be referred to actions or strategies intended to address environmental or societal challenges that ultimately lead to negative outcomes or impact existing problems. It occurs when well-intentioned responses to environmental changes, such as climate change, fail to consider the broader ecological and social dynamics or inadvertently worsen the situation (Magnan et al., 2016). According to Neumann et al. (2015), the

construction of seawalls and other hard coastal protection structures in response to rising sea levels and increased storm events can be seen as maladaptation in many coastal communities. The authors explained that while these structures may provide short-term protection against flooding and erosion, they can have unintended negative consequences. Seawalls, for instance, can exacerbate beach erosion and disrupt natural coastal processes, leading to the loss of valuable sandy beaches and harming local ecosystems. In the long run, this approach can be unsustainable and costly, as it does not address the root causes of coastal vulnerability and can even increase risks over time.

Resilience

Resilience in the context of social-ecological systems refers to the capacity of a system to withstand disturbances, adapt to changes, and maintain its fundamental functions and structures while continuing to provide critical ecosystem services (Folke et al., 2010). Resilience is not merely about bouncing back from shocks; it involves learning and transformation to enhance the system's ability to navigate future uncertainties (Béné et al., 2012; Brown, 2015). Therefore, that system is able to absorb disturbances while retaining the same basic structure and ways of functioning, responses for self-organization, and responses to adapt to stress and change (Walter et al., 2018). Resilient systems often rely on strong connections and feedback between their components (Fabricius, 2016). These connections facilitate the flow of information and resources, enabling rapid responses to disturbances (Bernhardt & Leslie, 2013).

Basin of attraction

The "basin of attraction" is a concept commonly used in the context of complex systems and resilience lenses, particularly in the study of social-ecological systems. It refers to the range of conditions within a system that can lead to a stable state or outcome (Lansing et al., 2014; Westley et al., 2013). In the context of social-ecological systems, the basin of attraction represents the various states or conditions that a system can exist in while maintaining its stability and resilience (Cinner & Barnes, 2019; Walker et al., 2004). For Indigenous communities, the "basin of attraction" highlights the importance of navigating their social-ecological landscape to find and maintain states that enhance their resilience, well-being, and cultural continuity (Viñals et al., 2023). It acknowledges that different practices, strategies, and governance approaches can lead to distinct outcomes within social-ecological systems (Bennett et al., 2021). By considering the basin of attraction, researchers and policymakers can better comprehend the range of possibilities for

Indigenous communities and work towards strategies that help these communities move towards more desirable and resilient states within their social-ecological systems.

Conceptual framework

This study is built on two combined lenses. Social-ecological system lens and the concept of resilience. Galappaththi et al. (2019) and Ford et al. (2020) have applied both lenses in developing conceptual frameworks. Conceptual framework developed by Ford et al. (2020) examines the resilience of Indigenous peoples in the face of environmental change. The resilience framework mirrors key lenses and theories such as social-ecological systems, adaptation, and governance structures, emphasizing the interconnectedness of these elements (Brown, 2015). Galappaththi et al. (2019) examined community adaptations to social-ecological change with a focus on small-scale fisheries. The social-ecological system framework in Galappaththi et al. (2019) examines how the integration of resilience thinking and development studies could create a better understanding of the implications of social-ecological change and policy development. The framework from the two theories used in this research views the framework of Ford et al. (2020) through the lens of coastal social-ecological systems. Using this framework, I addressed the relationship of Indigenous communities with place, agency, institutions, collective action, Indigenous knowledge, and learning in their responses to perceived social-ecological system changes like climate change, resource change, biodiversity loss and pollution (Ford et al., 2020; Galappaththi et al., 2019).

1.3 Study Area

The coast of Ghana has a wide range of biophysical features. Ghana's coastal area occupies a land mass of 550km which is characterized by river basins, the Gulf of Guinea, and geomorphological and tectonic processes (Evadzi et al., 2018). According to Adortse (2019) as shown in Figure 1.3, Ghana's coast has three geomorphological zones namely: 1. western coast which is about 95 km and is geologically made up of fine sand, gentle beaches, and coastal lagoons, 2. central coast which is about 321 km and is made up of an embayed coast of rocky headlands, rocky shores, littoral sand barriers, coastal lagoons, and 3. the eastern coast which is about 149 km and comprises sandy beaches, the deltaic estuary of Volta River (Adortse, 2019; Addo & Lamptey, 2013). The main occupation of inhabitants along the eastern coast of Ghana is fishing, farming, transportation of goods and services, sand and stone mining, oil extraction, and tourism (Adortse, 2019; Evadzi et al., 2018; EPA, 2000). The eastern coast has rich and diverse resources such as fisheries and

biodiversity, oil and gas, wetlands and mangroves, lagoons and estuaries, sandy and rocky beaches, sea turtles, manatees, whales, dolphins and birds, historical monuments, ports, and harbors (Babson, 2020).

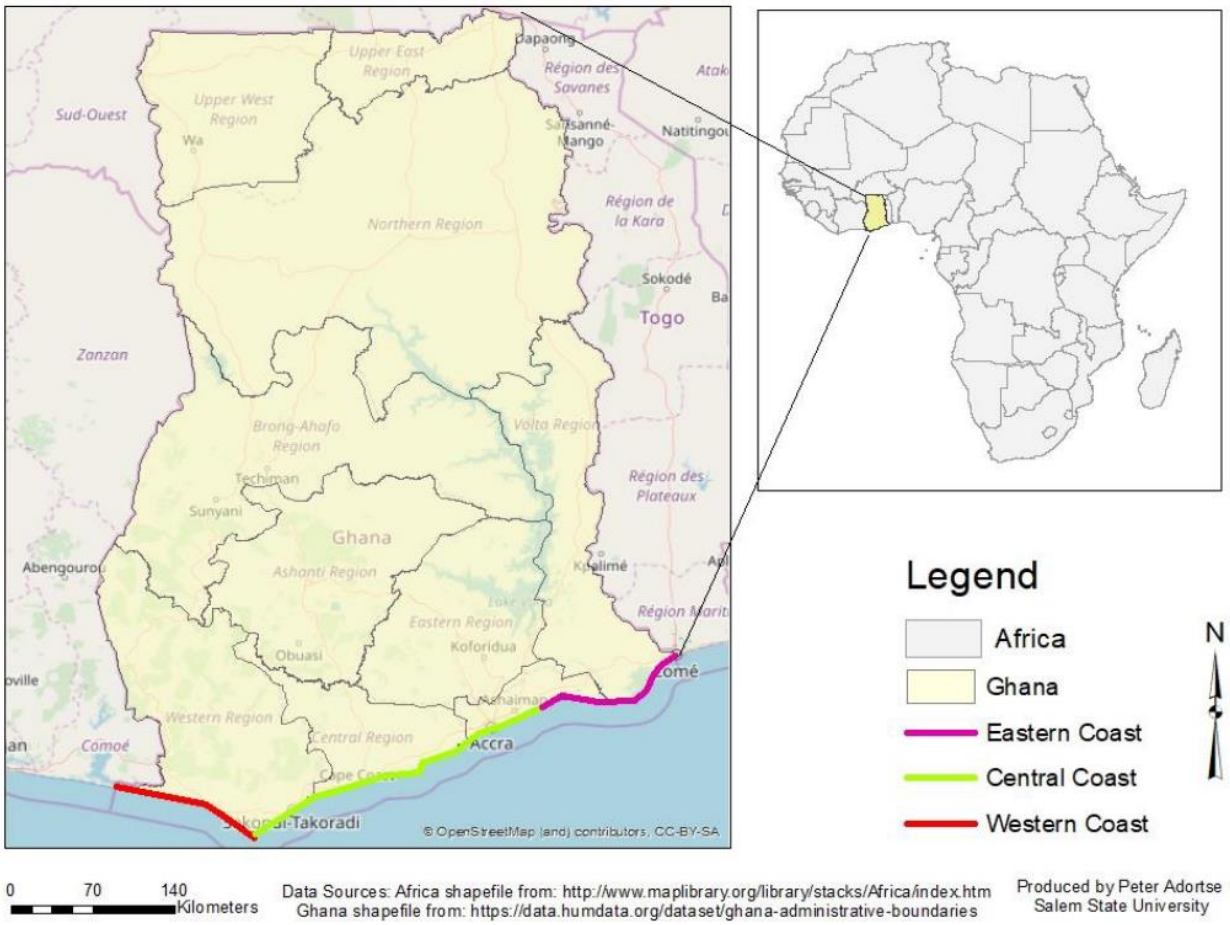

Figure 1.3**:** Map of Ghana and sections of the coastal zone highlighted. Akplabanya in Ada West district is on the eastern coast of Ghana. Source: This image was adapted from Adortse (2019, p 9)

1.4 Small-scale fisheries in Ghana

Ghana is one of the countries that contributes to fish production in Africa (Hasselberg et al., 2020; Alabi-Doku et al., 2018). The fisheries sector can be categorized into two sectors, marine/coastal fisheries, and inland/freshwater fisheries (Janananda, 2021). The marine/coastal sector can be further divided into four subsector fishing units namely small-scale fisheries, semi-industrial fisheries, industrial-fisheries, and tuna fisheries (Nunoo & Asiedu, 2013). The fishing industry in Ghana contributes importantly to the national economic development with about 4.2% of GDP,

and out of that 80% of this contribution can be attributed to small-scale fisheries (FAO, 2022). The small-scale fisheries subsector is operated from 304 landing sites in 189 fishing villages located along the coast, and about 1.5 million people depend on it for their livelihood (FAO, 2022) including Akplabanya. The small-scale industry employs both men and women, whereby men are involved in fish harvesting and all other activities to catch fish while the women are the key players in onshore post-harvesting activities like processing and selling the processed fish (Nunoo & Asiedu, 2013).

Indigenous coastal communities in Ghana are at risk (Codjoe et al., 2014; Yankson et al., 2017b). As fishing activities and canoes increase in Indigenous fishing communities like Akplabanya amidst climate change, the coral reef is changing, and fish catch is drastically declining (Belhabib et al., 2019; Nyong & Niang-Diop, 2006). According to Cinner et al. (2012), climate change impacts such as higher temperatures have the potential to affect coral reef ecosystems, which are habitats of various species of fish, in a process called coral bleaching. Cinner et al. (2012) further explained that livelihoods of fishers in coastal communities depend on thriving coral reefs and any disturbance to the reef make social-ecological system in coastal communities vulnerable (Cinner et al., 2012). According to Lazar et al. (2018) in the Ghana Sustainable Fisheries Management Project by USAID, fish catch per unit effort is declining in marine small-scale fisheries as shown in Figure 1.4. This can be attributed to both human and climate factors such as increasing population, bad fishing practices, and ocean warming respectively (Nunoo & Asiedu, 2013).

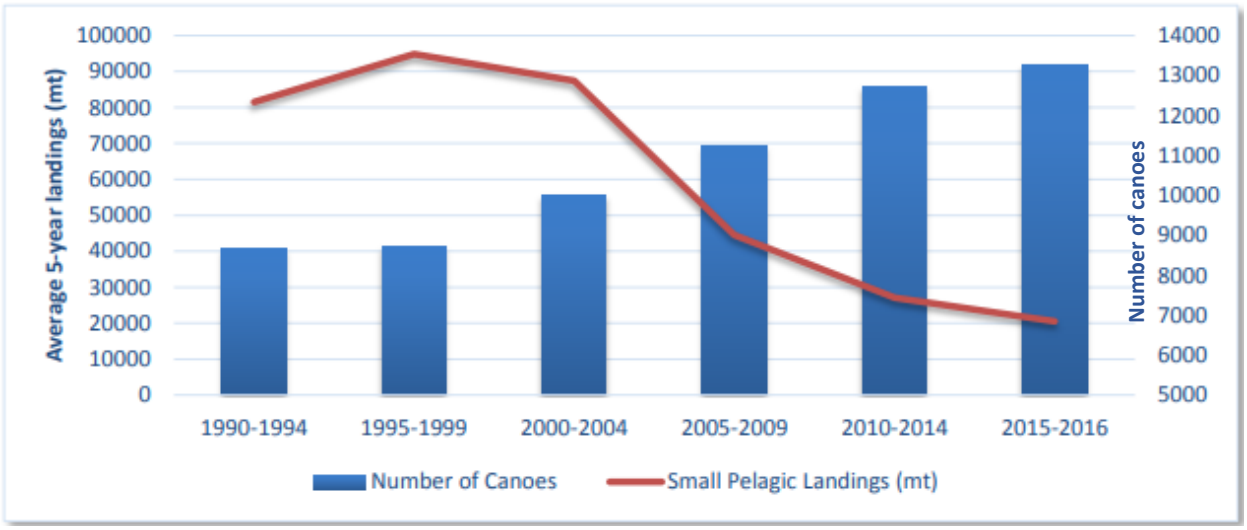

Figure 1.4: **S**mall pelagic fish stocks (Sardinellas, Anchovies, and Mackerel) in orange and blue in the number of canoes targeting small pelagics from 1990 to 2016 in Ghana adopted from Lazar et al. (2018) and Asiedu et al. (2021).

The responses of fishers, especially on the western coast of Ghana to low fish catches have not been ideal (Danquah et al., 2021; Freduah et al., 2019). Mostly, fishers move farther offshore and use special gear to fish and over-exploit (Perry et al., 2011). The most commercially important and overly exploited pelagic in Ghana's coastal fisheries are the sardinellas, specifically round sardinella (*Sardinella aurita*) and Madeiran sardinella (*S. maderensis*) which occur in the entire Gulf of Guinea (Lazar et al., 2018). During the upwelling seasons, other fish species commonly caught in Ghana's waters including cassava fish, flat sardinella, largehead hairtail, moonfish, red pandora, red snapper, skipjack tuna, yellowfin tuna, groupers, cuttlefish, burrito, red fishes (*Sparidae*) and burros (*Pomadasidae*) are also exploited (Asiedu et al., 2021; Lazar et al., 2018). Adaptation strategies such as fishing holidays and seasonal closures, which were effective in the past, are currently less successful due to economic hardships in Ghana and limited communication between fishers and the Fisheries Commission, leading fishers to continue fishing during these periods (Adom et al., 2019).

Figure 1.5**:** 2030 Scenario mapping of Akplabanya and its neighboring communities completely below the water level of 1 meter using the coastal risk screening tool (Climate Central 2023).

Akplabanya is one of the fishing communities of the Ada West district (GSS, 2014). The area is almost flat and descends gradually to the Gulf of Guinea (Mensah et al., 2006). The total population of Akplabanya as of 2010 was 5,101 which is the third-largest community in Ada West District (GSS, 2014). Albeit the total population in 2000 was 4,272 and in 2021 was 7,816 (GSS, 2008, 2021). Akplabanya experiences devastating floods from tidal waves, warmer temperatures exacerbated by hot weather, air pollution, and a high potential range of vector-borne infectious diseases (Darko et al., 2022). Fishers (men who fish) in Akplabanya repetitively lose their boats, likewise, fishmongers (women who process fish) lose their clay-built smoking ovens while their children stand to lose their means of education as floods destroy school buildings (OMP, 2022). These characteristics of Akplabanya make the Indigenous fishing community highly vulnerable and failure to build high adaptive responses may result in the loss of the entire Akplabanya fishing community as seen in Figure 1.5. Using the 2030 projected scenario map from Climate Central, Akplabanya can be seen completely submerged at a water level of one meter using the coastal risk screening tool.

1.5 Disasters in Akplabanya

Ongoing climate events like more frequent and severe tidal and storm surge flooding are impacting fishing communities like Akplabanya in Ada West (Babson, 2020; Cudjoe & Kwabla Alorvor, 2021). During floods from tidal waves, there is the likelihood that fishers lose their canoes and other fishing gear, and fishmongers who process the fish also lose their clay molded ovens through flooding as well (OMP, 2022). Economic activities cease during tidal coastal floods in Akplabanya. For instance, an Indigenous fishing community called Fuvemeh in the eastern coastal zone of Ghana lost its school building three times due to floods from tidal waves. Fishers and fishmongers of Fuvemeh eventually gave up on fishing and about 80% relocated to seek work (VOA, 2021). According to VOA (2021), Fuvemeh is almost extinct due to floods from tidal waves as a result of sea-level rise. This could be the future of Indigenous fishing community of Akplabanya if appropriate adaptation strategies are now in place.

Certain government activities on the coast of Ghana have been impacted by climate (Ayilu, 2023). The construction of the 8,502-square-kilometre Akosombo dam on the Volta River in 1965 deprived the eastern coastal zone of Ghana of adequate sand replenishment resulting in erosion along the shoreline (Babson, 2020). The recent expansion of the Tema port has also impacted sediment flow (Addo, 2021). These have contributed significantly to the recurrent floods from tidal waves and erosion along Ghana's eastern coastal zone with the likelihood to affect the ecological systems present at the coast (Addo, 2021; Evadzi et al., 2018). As part of the government adaptation strategies in the eastern coastal zone, the government built the Keta Sea Defense (Figure 1.6) to protect and stabilize the shoreline from Keta to Hlorve (Evadzi et al., 2018). The government's main aim of the Keta Sea Defense project is to prevent chronic and periodic coastal erosion and flooding. Unfortunately, the Keta Sea Defense system does not protect the entire eastern coastal zone (Evadzi et al., 2018), exposing Indigenous communities like Akplabanya to the increased tidal waves and floods as a result of sea-level rise which in combination with higher temperatures, partly disrupt the coastal social-ecological system that supports the livelihoods of fishing communities.

Figure 1.6: An Aerial photograph of the Keta Sea Defense Works Project (KSDW) adopted from Research Planning Inc.

1.6 Adaptation in Akplabanya

There are few key policy adaptation strategies in Ghana to address climate change (Evadzi et al., 2018). The National Adaptation Strategy (2011) and the National Marine Fisheries Management Plan (2015-2019) acknowledge the ongoing impact of climate stressors like rising temperatures, SLR, extreme weather, and declining rainfall and increased rainfall variability but have yet to implement the plan in Indigenous fishing communities like Akplabanya (Ameyaw et al., 2021; McNally et al., 2021; Yang et al., 2019). The national adaptation strategy prioritizes ten adaptation programs and plans to implement the programs at five institutional levels in decreasing order, namely, national, regional, civil society organizational levels, district, community levels (MoFAD, 2015) but does not address coastal social-ecological system at all these levels. The national marine fisheries management plan aims to implement several key measures, including ending open access in artisanal fisheries, completing canoe registration, introducing a fishing licensing program for artisanal fisheries, implementing additional fishing holidays, adopting a co-management policy involving stakeholders in a transparent process, and enhancing enforcement responses and resources (Lazar, 2018) but does not address coastal social-ecological system changes. Though

institutions have strategies and practices underway, effective adaptation seems unlikely as there are knowledge and research gaps on social-ecological system in coastal Ghana impacted by climate change.

1.7 Problem statement

Akplabanya Indigenous community heavily relies on small-scale fisheries for its livelihood. Despite the significant contribution of small-scale fisheries to Ghana's national economy, Akplabanya is grappling with climate change impacts such as coral reef degradation, declining fish catches, and coastal flooding. These environmental changes are compounded by over-exploitation of commercially important pelagic species, leading to low fish catch rates (Asiedu et al., 2021; Perry et al., 2011). Adaptation strategies, including restrictions on fishing during holidays, have become less effective due to economic hardships and limited communication between fishers and authorities (Lazar et al., 2018). Additionally, Akplabanya faces the looming threat of complete submersion under a meter of water by 2030, as projected by Climate Central's coastal risk screening tool (Figure 1.5). In this context, adaptation interventions are urgent for the survival of Akplabanya. However, more baseline knowledge is needed about the ongoing changes of human-environment interaction in Akplabanya or their responses to these coastal changes. The study aims to identify these challenges and examine key adaptation practices to enhance the resilience of Akplabanya's Indigenous fishing community in the face of climate change impacts.

1.8 Research Aims and Objectives

The aim of this research is to assess the opportunities for climate change adaptation in Akplabanya Indigenous coastal community in Ghana. This research has two objectives, which are:

1) To identify changes in coastal human-environment interactions as perceived by the Akplabanya Indigenous community, and

2) To examine the human adaptation responses of the Akplabanya community to changes in coastal human-environment interactions.

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Chapter 2: Perceived social-ecological changes and adaptive responses in coastal Indigenous community of Akplabanya, Ghana

Abstract

Coastal areas across the globe, where more than 60% of the world's population resides, are increasingly susceptible to the impacts of climate change, including heightened storm activity, rising sea levels, and coastal erosion. Even though literature explores climate change impacts in African countries like Ghana, less is known about the ongoing changes affecting coastal Indigenous communities. Thus, this paper focuses on Akplabanya. The two study objectives are: (1) To identify changes in coastal human-environment interactions as perceived by the Akplabanya Indigenous community, and (2) To identify the key human adaptation responses of the Akplabanya community to those changes. Semi-structured interviews (n=61), key informant interviews (n=28), focus group discussions (n=3 (5 each)), and participant observation (2 months) were used to collect data to address these objectives. The community's responses to these changes varied, encompassing coping mechanisms, transformative actions, and adaptation strategies. I found five themes to explain Akplabanya's perceptions about the changes of coastal human-environment interactions. They are: 1). Biodiversity loss (e.g. vegetation loss), 2). Pollution (e.g. unsustainable practices), 3). Coastal climate change (e.g. coastal erosion), 4). Resource change (e.g. freshwater change), and Population change (e.g. increasing population). I also built responses from participant that addressed objective 2 on themes of place, agency, collective action, institutions, coastal Indigenous knowledge, and learning. The findings built on these themes highlight changes in coastal human-environment interactions that impacted coastal fisheries, water systems, land utilization, livestock management, architectural practices, and the preservation of Indigenous knowledge in Akplabanya. This study contributes to a deeper understanding of changes in coastal human-environment interactions in Akplabanya. By identifying the adaptive strategies devised by the community and the role played by local and government institutions, the study provides insights into the adaptation measures required to enhance and adjust the community's resilience to ongoing environmental change.

2.1 Introduction

2.1.1 Background and Problem Statement

Over 500 million people live in coastal systems (Hasim, 2021; IPCC, 2019). The coast is one of the most diversified ecosystems in the world because of the abundance of marine resources (Hossain et al., 2020; Inácio & Umgiesser, 2019). This is due to its marine resources, highly fertile low-lands, water transportation resources, beautiful scenes with recreational opportunities, and Indigenous people (Ateme, 2021; Inácio & Umgiesser, 2019). These coastal resources support the people living in the coastal systems (Hobday et al., 2016). Meanwhile, the coast face a myriad of challenges, including the impacts of climate change, sea-level rise, coastal erosion, and pollution (Thirumurthy et al., 2020; Lane et al., 2015). Understanding complex interactions between social and ecological systems in coastal areas is crucial for devising effective strategies to enhance

resilience, adapt to changing conditions, and promote sustainable resource management (Adger et al., 2005).

The interconnections between coastal ecosystems and social systems have seen drastic changes in the past 60 years (Refulio-Coronado et al., 2021; Swart et al., 2018). This can be viewed through the lens of coastal social-ecological systems (Hossain et al., 2020). Social-ecological system (SES) refers to the interdependence of social and ecological components, recognizing that human activities and environmental conditions in coastal regions are intricately linked and influence each other (Hossain et al., 2020; Fischer et al., 2015; Berkes et al., 2003). This interdependence shows the resilience of coastal systems are deeply entwined with the well-being and behaviors of the communities dwelling in these areas (Bernhardt & Leslie, 2013; Folke, 2006). Coastal social-ecological system studies emphasize the dynamic nature of these interactions, highlighting the critical importance of understanding how social and ecological factors coalesce and evolve over time (Adger et al., 2005; Olsson et al., 2007).

While human activities interdepend on coastal ecological, global climate change plays a role in impacting that interdependency (Chakraborty et al., 2020; Hewitt et al., 2016; Hyndes et al., 2014). The impact can be seen in the timing, and distribution patterns of temperature, precipitation, oceanic and atmospheric circulation, and sea levels (Malakar et al., 2023; NGS, 2022) affect coastal social-ecological system significantly (Hewitt et al., 2016). For instance, storms and hurricanes have been associated with more frequent and intense weather events. Increased flooding and coastal erosion have occurred as a result of rising global temperatures attributed to the increased emissions of greenhouse gases (Franchini & Mannucci, 2015; Robinson, 2021; Rosario et al., 2019). Moreover, changing precipitation patterns and rise in sea level has disrupted the natural freshwater input into coastal ecosystems and caused land loss (Day & Rybczyk, 2019; Garner et al., 2015). Such disruption has led to shifts in species composition and biodiversity (Ghalambor et al., 2021; Laurino & Turra, 2021; Li et al., 2020) and impacted key components of coastal activities like fisheries and aquaculture (Frusher et al., 2016; Johnson et al., 2020; Koehn et al., 2022).

Indigenous peoples living on the global coast are among the vulnerable communities that are affected by climate change (Ford et al., 2020; Billiot & Parfait, 2019; Cisneros-Montemayor et al., 2016). The World Bank (2023) referred to Indigenous peoples as distinct social and cultural groups with deep ancestral ties to their territories and resources, depending significantly on natural

resources. In the case of Ghana, similar to many other African nations, there are Indigenous communities residing along the coast (Codjoe et al., 2014; Yankson et al., 2017). As outlined by Ospina et al. (2012), these Indigenous communities along the coast of Ghana are grappling with climate change impacts such as depleting fish stocks, extensive coastal erosion, and severe flooding. These climate change impacts emphasize the need for culturally sensitive interventions to address these issues and enhance the community resilience of Indigenous coastal communities in Ghana (Arkhurst et al., 2022; Yang et al., 2019).

While literature exists on coastal social-ecological system globally, there are limited studies with this lens in Ghana (Amadu et al., 2021; Williams et al., 2020). In few studies that focus on Ghana, little is known about the present effects of social-ecological system changes on Indigenous peoples, or the Indigenous peoples' reactions to these changes (Ferro-Azcona et al., 2019; Freduah et al., 2019). Although the ongoing physical changes, such as sea erosion and inundation of Ghana's coastline, have been recorded, there is still the need to address human-environment interdependence while been impacted by climate change (Arkhurst et al., 2023; Boateng, 2012; Evadzi et al., 2018). Akplabanya, an Indigenous coastal community in the Ada West District of Ghana, has little research documented on the ongoing coastal social-ecological system changes in the community (Cudjoe & Alorvor, 2021; Dada et al., 2021; Loch & Riechers, 2021). Addressing these gaps through research is crucial to better understand the unique challenges this Indigenous community faces through the lens of coastal social-ecological system exacerbated by climate change impacts (Dada et al., 2021; Duku et al., 2022).

The two research objectives of this study are to: O1) Identify perceived social-ecological system changes in Akplabanya and, O2) Examine the key adaptation responses to the perceived social-ecological system changes. Akplabanya is one of the coastal communities in the Ada West district currently going through major coastal social-ecological system changes in their water systems, land, vegetation, and food resources (Babson, 2020). This has led to multiple threads of negative changes in the livelihoods of these Indigenous people (Atiglo et al., 2022). Akplabanya's unique vulnerabilities and Indigenous cultural perspective, coupled with its localized adaptation responses, scarcity of research, and the potential policy implications, collectively shows the significance of studying this coastal community within the context of social-ecological system (Dada et al., 2021; Duku et al., 2022). Through this study, valuable insights can be extracted to inform broader strategies for climate resilience and sustainable development in similar coastal

settings around the world. In the following subsections, I will explain methods and findings of both objectives. I will then discuss key findings that emerged from the results, compare to global literature, and conclude.

2.2 Methods

2.2.1 Conceptual approach

This study uses resilience conceptual framing by Ford et al. (2020) (Fig 2.1). The conceptual framework is a lens available to assess Indigenous environment and climate change (Anderson et al., 2016; Ford et al., 2020; Garnett et al., 2018). Interactions between these perceived changes and responses can be viewed through the lens of coastal social-ecological system framework from the work of Galappaththi et al. (2020). From the conceptual framework of Ford et al. (2020), I used both resilience and social-ecological system concepts to assess the coastal fisheries system in Akplabanya. Though the conceptual framework of Ford et al. (2020) explained socio-economic and environmental change, fisheries system in Akplabanya is not significantly impacted by the socio-economic changes as shown in Fig 2.1. Therefore, I focused on the themes of environmental change drivers as codes for data analysis. These codes are freshwater use, land use change, climate change, biodiversity loss, and pollution as shown in the conceptual framing (Ford et al., 2020). Further, I addressed adaptation, coping, transformation, and resilience responses of people of Akplabanya while simultaneously influenced by themes like place, collective actions, learning, agencies, local institutions, and Indigenous knowledge, also used as codes as shown in Fig 2.1.

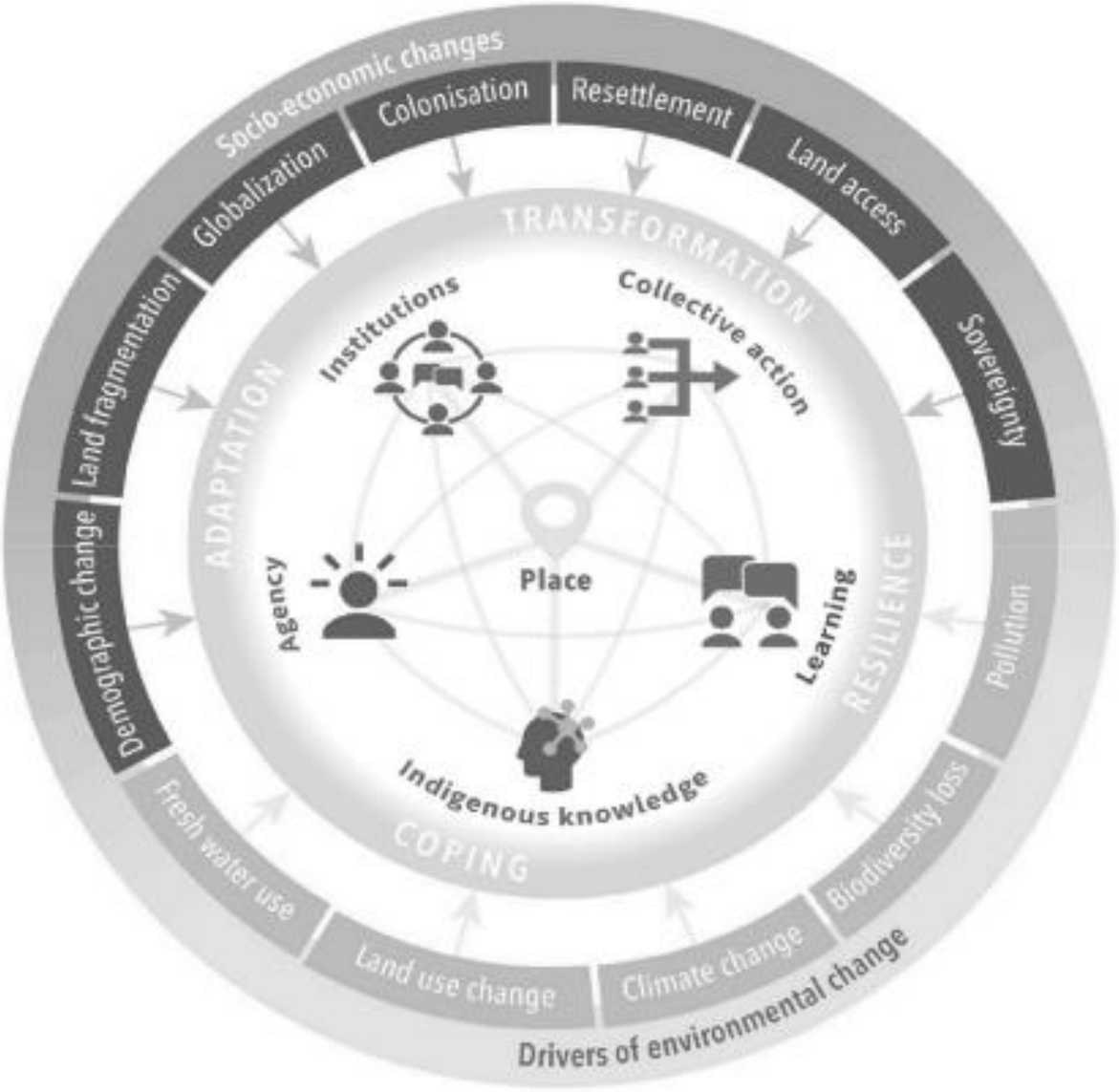

Figure 2.1: The interplay of environmental and human factors in shaping the resilience of indigenous peoples to environmental change processes (Ford et al., 2020; p539).

Environmental change drivers encompass freshwater use, land use changes, climate change, biodiversity loss, and pollution, aligning with the conceptual framework proposed by Ford et al. (2020). My study also delved into the adaptive, coping, transformative, and resilience responses of the Akplabanya community. These responses were simultaneously influenced by broader themes such as place, collective actions, learning, agencies, local institutions, and Indigenous knowledge, all of which were integrated into the framework illustrated in Figure 2.1. Additionally, it's essential to note that while Ford et al. (2020) framework explicitly mentions environmental changes, other scholars have highlighted the role of climate change impacts, such as sea-level rise

and coastal erosion, as primary drivers of changes in factors like biodiversity loss, land use, and freshwater availability (Weiskopf et al., 2020; Zhi et al., 2022). These climate-related impacts can significantly influence the social-ecological systems of coastal communities, and my research aimed to capture these dynamics within the Akplabanya context.

2.2.2 Study area and people

The people of Akplabanya are a subset of Ada of the Dangme ethnic group (DPCU, 2014), which is located in the south-east of Ghana. The map below (Figure 2.2) shows the location of Akplabanya and its extents.

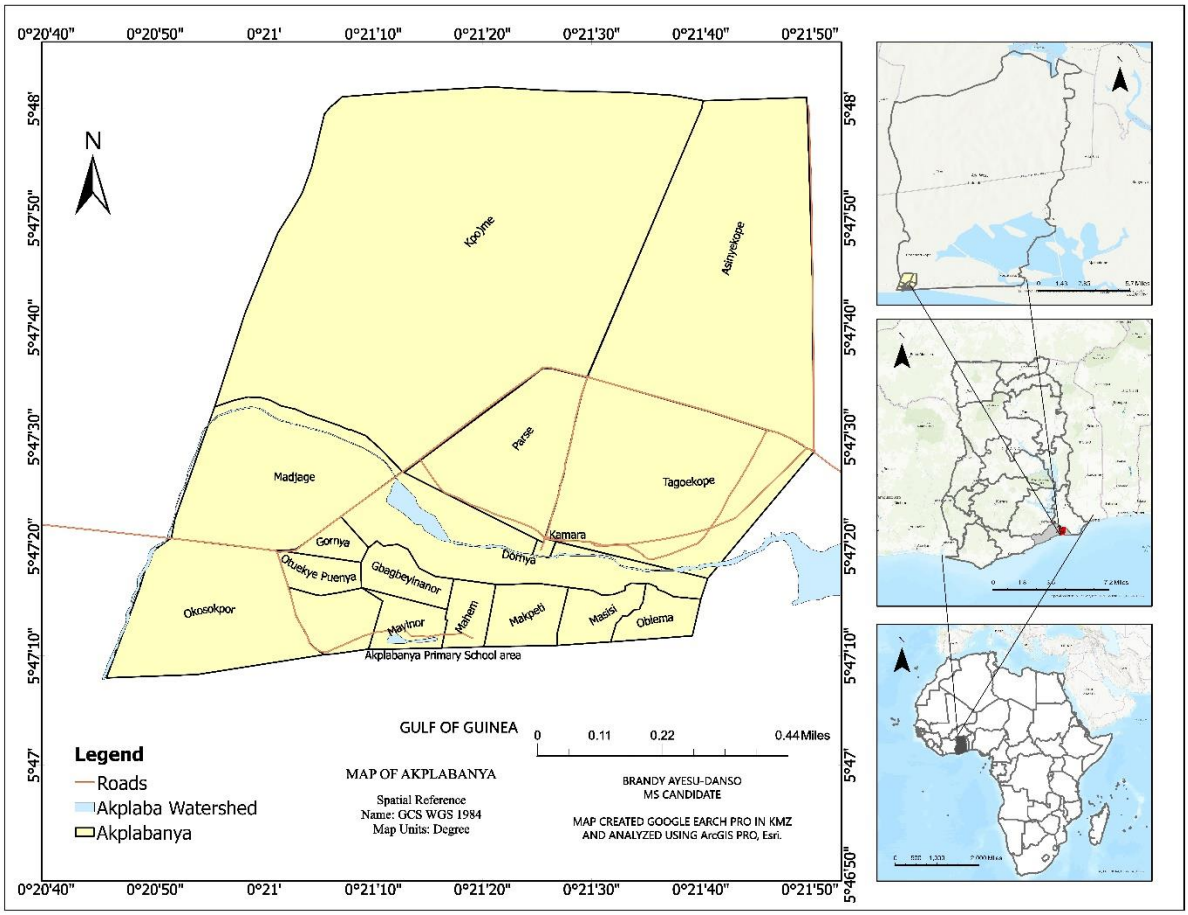

Figure 2.2: The map of Akplabanya; and its extents in Ada West, Greater Accra, Ghana, West Africa (created using Google Earth and ArcGIS Pro)**.**

2.2.3 Data collection methods

To address objectives of this study, I used four data collection methods over the two months of fieldwork in Akplabanya: participant observation, semi-structured interviews, key informant interviews, and focus group discussions. Before my fieldwork in Akplabanya, I obtained approval from the Virginia Tech's Institutional Review Board (IRB) (22-812), and I hired a translator and a fieldwork assistant to support the data collection process. I further sought permission from the chief of the community, and his cabinet poured libations to mark the beginning of my data collection process.

Data collection process comprised four phases. Participant observation was phase one and conducted through two-months. Semi-structured interviews were conducted for one month as phase two. Key informant interviews were phase three and lasted for three weeks. Focus group discussions were the fourth phase and completed within two days. I transcribed and coded collected data and conducted content analysis to deduce results of this study. Content analysis is a technique for examining qualitative data, such as transcripts from interviews, notes from observations, or documents as it provides a methodical, sequential approach to text analysis and enables theory- and data-driven code development (Puppis, 2019).

a) Participant Observation (PO)

I documented two months of daily observations in a field diary to address objectives 1 and 2 using participant observation. Participant observation is a research method in which the researcher engages in a sustained, immersive, and systematic observation of people, behaviors, and events within a specific social or cultural context while actively participating in the setting (Bernard, 2017: p. 219). Daily observations were conducted by walks through the community every single day, community mapping, time spent with fishmongers at work, and with fishers fishing with dragnet, playing board and card games, attendance of community events, and meetings with the chief of Akplabanya with his cabinet and the chief fisherman. I used these opportunities to observe and took photos and videos to verify responses to coastal social-ecological system changes impacted by sea-level rise, coastal erosion, storm surges, and changes in precipitation and temperature patterns in Akplabanya. These documented observations, photos and videos were coded with responses from semi-structured interviews and its emerged themes and subthemes to address O1 and O2.

b) Semi-Structured Interviews (SSI)

I conducted semi-structured interviews as the second phase of my data collection. Semi-structured interviews follow a list of predetermined open-ended questions, where the interviewer allows conversation to unfold so interviewees can explore issues they think are most important Longhurst (2010). I conducted video and audio-recorded interviews with fishers, fishmongers, and other community members involved in other livelihood activities using the topic guide I created as shown in Appendix B. I recorded data on the characteristics of households of responders, their perceived social-ecological system changes in the community, and their responses to their perceived social-ecological system changes using the topic guide. I used snowball and random sampling techniques to recruit sixty-one (*n= 61*) participants as shown in Table 2.1. Snowball sampling technique is used in finding, identifying, selecting, and taking samples in networks or chains of relationships in field research. In this case, the Assemblyman was the primary contact who led me to other members of the community. These participants were fishers who sat at the beach or were retired at home, fishmongers who worked close to the *Akplaba* (river in the community), and all other members scattered throughout the community. The interviews lasted between one hour to two and half hours depending on the participant. I recorded participants' responses until reaching saturation. Saturation in qualitative research is often used as a methodological concept to discontinue data collection and/or analysis (Leese et al., 2021).

c) Key Informant Interviews (KII)

I used key informant interviews as the third phase. I used KII to track the history of perceived social-ecological system changes (O1) and the history of responses to perceived social-ecological system changes (O2) by participants documented from SSI. KII is a qualitative research method that involves in-depth conversations with community individuals who possess specialized knowledge and expertise in Akplabanya (Lokot, 2021). I used snowball sampling techniques to recruit participants. I interviewed twenty-eight key informants, however, one recording got corrupted which made the total number twenty-seven (*n=27*) as shown in Table 2.1. Key informants I interviewed are the chief fisherman, heads of committees (Landing beach committee, Canoe Fishermen's Association, and Premix Fuel committee), and veterans of fishers and fishmongers. I recorded village profile (market centers, accessibility), timeline of key perceived social-ecological system changes, fishing seasons and history of responses to perceived social-ecological system changes that were not covered by SSI. I used guiding questions like: how many years ago did Akplabanya begin to practice light fishing and what is the history surrounding it?.

Through the interview guide, I recorded knowledge, experiences, and practices of Indigenous communities in relation to their interactions with ecosystems and natural resources from participants over time to address O1 and O2.

d) Focus Group Discussions (FGD)

I conducted focus group discussions as the fourth phase to validate already recorded observations and responses from PO, SSI, and KII. Focus group discussions are essential in gathering qualitative research data, by interacting with a small number of people in an informal setting for group discussions on a specific topic or issues (Onwuegbuzie et al., 2009; Wilkinson, 2004). I developed the topic guide for FGD based on data collected through PO, SSI and KII (Appendix C). I conducted three FGD on two different days with a total of fifteen (n=15) participants during our fieldwork by the research team. I used snowball sampling techniques to recruit the fifteen (n=15) participants as shown in Table 2.1. I conducted all discussions in dry season of January 2023 with five (5) participants per group. The discussions lasted between two and a half to three and a half hours. The first FGD was video recorded while the other two were audio recorded. FGD one aimed to validate the list of documented perceived social-ecological system changes (O1) and understand the level of agreement and direction of identified change. Three of the participants were males and were experienced fishers (40-50 years old (n=3)). The other two were females and experienced fishmongers (35-45 years old (n=2)).

In FGD two, I aimed to validate documented responses to perceived social-ecological system changes (O2) and understand the level of agreements, structures of adaptation and maladaptation. Four of the participants were males who were experienced fishers (50-60 years old (n=4)). One was a female who was an experienced fishmonger (45-55 years old (n=1)). FGD three aimed to validate the links between perceived social-ecological system changes impacted by CC, their responses to these perceived social-ecological system changes, structures of adaptation, limitations of adaptation responses, and maladaptation. Three participants were males of which two were experienced fishers (50-65 years old (n=2)) while the other male was an experienced local health worker (45-55 years old (n=1)). Two of the participants were females who are experienced fishmongers, one who had retired and currently sells government pipe-borne water (60-70 years old (n=1)) and the other is still a fishmonger (35-45 years old (n=1)). The native translator moderated all three discussions, the field assistant video recorded the first discussions and I audio recorded the FGD 1 & 2.

Table 2.1: Summary of data collection during fieldwork in Akplabanya

	Participant Observation	**Semi-Structured Interviews**	**Key Informant Interviews**	**Focus Group Discussions**
Phase	One	Two	Three	Four
Period	Two months	One month	Three weeks	Two days
Number of participants	Community members	61	27	3
Participants	Community members	Fishers, fishmongers, traders, teachers, mechanics	Chief Fisherman, heads of committees, fishers, and fishmongers	These were mixture of fishers, fishmongers, traders, heads of committees
Data	Field notes Pictures and videos	Characteristics of households The changes and key responses	Community specific and historical data on changes and key responses	Verifying data collected from participant observations, semi-structured interviews, and key informant interviews

2.2.4 Data coding and analysis

The analysis of the data proceeded from the very beginning of the two-month fieldwork. I organized the recorded data and began transcribing video and audio recordings of FGD, PO, and SSI while in Akplabanya. KII was the last to be transcribed. I completed all transcriptions in six months after the fieldwork was completed. I began coding while transcribing, however, it was after the fieldwork. I coded transcripts from SSI based on the topic guides used to collect data for O1 and O2 in Microsoft Excel. For O1, the topic guide was based on how climate change has impacted social-ecological systems like the coastal fisheries system and resources like fish, freshwater, land, vegetation, and livestock in the community associated with it. The codes were similar to the drivers of environmental change mentioned in the conceptual framing (Fig. 2.1) which are climate change, land use change, freshwater use, biodiversity, and pollution.

However, concerning the climate change code, the transcripts of SSI had evidence of specific climate change impacts. These impacts like sea-level rise, coastal erosion, tidal surges, and changes in rainfall patterns are only relevant to the coast. Therefore, I termed it coastal climate

change. Though the transcripts from the SSI showed similarities with the conceptual framework I used, there were few differences. The climate change from the drivers of environmental change in the framework was not the only code I changed. Concerning the freshwater use and land use change codes, the transcripts of SSI termed them as resources, therefore I merged both into one code. Furthermore, I considered patterns not aligned with codes from the framework as new drivers of environmental change. The codes for O1 became themes and subthemes supported by frequency of quotes from SSI transcripts as well as pictures and photos from PO as shown in Fig 2.3.

For O2, the topic guide for SSI was based on the responses to perceived social-ecological system changes. That is, how participants responded to changes in fish, freshwater, land, vegetation, and livestock as per the transcripts of SSI. The pattern in transcripts by participants were similar to six ways of response to changes in social-ecological system as shown in the framework (Fig. 2.1). I used these six ways of response to changes in social-ecological system as codes. I manually compared and categorized quotes under these six ways of response. Afterwards, I linked these codes to quotes from the transcript of SSI participants that explained individual, collective, and institutional responses. These codes became themes and subthemes to address O2 as shown in Fig 2.3.

The purpose of KII and FGD is to support themes that emerged from the analysis of SSI. The KII guide I used was in the form of tables, therefore, I transcribed it in that same format. All transcriptions were done alongside coding to track the history of perceived social-ecological system changes (O1) and the history of responses to perceived social-ecological system changes (O2) by participants documented from SSI. I manually compared and categorized the historical data I tracked to deduce patterns, and figures to support the codes from SSI. I linked photos and videos to the information deduced from KII. On the other hand, I used the FGD guide to validate data from SSI and KII, and highlighted changes that had not been mentioned. The guide was made up of quotes that supported SSI and KII. The agreement levels from each discussion either supported or debunked quotes supporting the identified themes and subthemes. FGD one cross checked quotes addressing O1, FGD two verified quotes addressing O2, and FGD three addressed structures interactions and institutions involved in responding to perceived social-ecological system changes (O2) that were not mentioned in SSI and KII. Participants in FGD three described these structures of interactions and institutions and I represented them with figures as results. Fig 2.3 summarizes the themes and subthemes that emerged after I analyzed the data I collected.

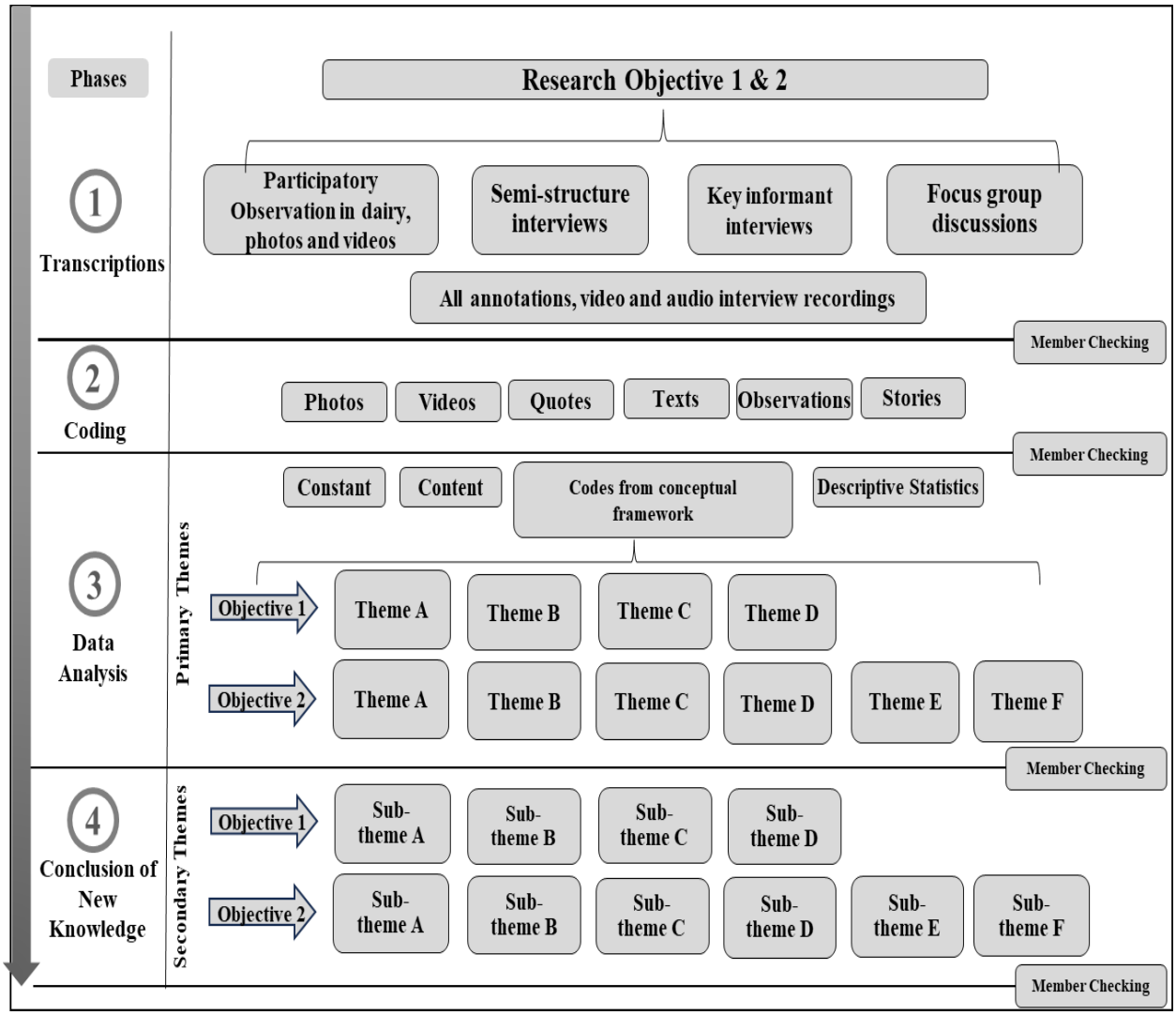

Figure 2.3: Data analysis process

2.2.5 Ethical considerations

I adhered to the ethical guidelines of the IRB Protocol, including informed consent from participants, confidentiality, and respect for cultural norms and traditions (Babb et al., 2017). The IRB approved consent forms for all four data collection methods that were used during the fieldwork. At the beginning of all interviews, I specified that I would not be gathering any identifiable information like their names (DuBois et al., 2018). I then reiterate that their withdrawal from the project will not result in any negative consequences (Babb et al., 2017). I relayed the option that the study participants had to choose the location of the semi-structured interview, participant observation, and key informants data collection process. For instance, participants choose to be interviewed while seated at the beach mending their nets, while others prefer to be interviewed in their homes (semi-structured interview, participant observation, and key

informants). These data collection processes were arranged as if we were there to learn from their experiences (that is my positionality and putting the interviewee in 'command') (Akinyode & Khan, 2018).). I informed participants before the home visit that they were required to abide by local law regarding reporting of child or elder abuse/neglect. In such cases confidentiality may need to be broken and we would abide by local laws concerning such matters (Eastwood, 2015).

For key informant interviews and semi-structured interviews, I obtained verbal consent from participants before the interview respectively including chief representatives (Turcotte-Tremblay & Sween-Cadieux, 2018). I verbally reiterate that their participation in this study was voluntary. I also informed them that their responses would remain confidential and not be shared with anyone outside of the study group (DuBois et al., 2018). For participant observation, I recruited individuals during my daily involvement and volunteering with Indigenous people of Akplabanya (Musante & DeWalt, 2010). I explained the research to participants while the local interpreter read out the information about the study as well as the verbal consent form (Schaefer, G., & Wertheimer, 2010). Participants had the option to think about it for a couple of days before agreeing to the consent form. For focus group discussions, I obtained verbal consent from all participants before the workshops. Throughout workshops, I read the information about the study to the participants which was interpreted by the local translator. I informed participants before the beginning of the focus group that confidentiality was not guaranteed in a group setting. Meanwhile, I had reiterated in the consent form that all participants were to keep information shared during the session private (Farnsworth & Boon, 2010).

My positionality should affect this study including data collection and analysis. I acknowledge that I am a black woman who was born and raised in Ghana. My ethnic heritage traces back to the Ashanti and Akuapem ethnic groups of Ghana. In the community of Akplabanya, where I conducted my study, there were traditional gender roles, with men primarily engaged in fishing activities at the beach while women took on the roles of fishmongers, responsible for fish processing and childcare at home. During the initial week of my two-month research period, my presence as a female researcher raised some initial concerns among a few male fishers. However, the presence of a translator and a field assistant played a crucial role in resolving any doubts or concerns raised by the community members. Given the unique dialect of Ga-Adangbe spoken in Akplabanya compared to the more widely used Twi language in southern Ghana, collaborating with the translator and field assistant was essential for effective communication. It was important

for the participants to perceive me as a Ghanaian woman who understands the socioeconomic context of Ghana, allowing them to relate to the changes they are experiencing.

2.3. Results

Table 2.2: The characteristics of semi-structured interview participants to support community profiles interviewed. (*n=61)* (Full table in supplementary material (Appendix B)).

Location of the study site and Demographic themes and questions	**SSI Participants response**	**Description of response**
Born in Akplabanya	Yes= 54(89%) No= 7(11%)	The higher percentage of participants were born in Akplabanya, while the rest were born in other areas within the Dangme tribe.
Number of years lived in Akplabanya?	18-25= 5(8%) 26-35= 12(20%) 36-45= 13(21%) 46-55= 10(16%) 56 and above= 21(35%)	Most participants had lived in Akplabanya more than 56 years, while few of them had lived in Akplabanya for less than 25 years
Where participants live	South= 40(66%) West= 18(30%) East= 1(2%) Central= 1(2%) Not specified= 1(2%)	The entire settlement is densely populated in the south due to its proximity to the coast. Thus, a higher percentage lived in the south and the southwestern part of Akplabanya
Level of education 1. Never 2. Primary 3. Secondary 4. Tertiary 5. Graduate	Never= 25(41%) Primary= 22(36%) Secondary= 8(13%) Tertiary= 6 (10%) Graduate= 0	A higher percentage of participants had never attended school, those who did dropped out of primary school and a few others completed secondary and tertiary
Main job/jobs	Fisher= 33(54%) Fishmonger= 11(17%) Teacher= 2(3%) Canoe Wood seller= 1(2%) Business Trading= 3(5%) Fishing and another= 12(19%) None= 0	Most participants were fishers, followed by some fishmongers who combined other businesses with fish smoking during low fish catch. Other participants were fishmongers only, teachers, and others whose businesses depended on the fishing livelihood in Akplabanya
Range of monthly income in GH₵?	50-500= 13(21%) 501-1000= 11(18%) 1001-1500= 1(2%) 1501-2000= 4(7%) 2000 and above= 7(11%) No fixed amount= 25(41%)	Most participants could not tell what they earned within a month, nor could give an average range, while others said they earned less than GH₵500.
Have your family members or you ever lived outside of the community? Why did they leave?	No= 4(7%) Yes, other reasons= 51(83%) Yes, Climate related reasons= 6(10%)	While families of the responders had moved out of Akplabanya due to various reasons, few had relocated due to recurring floods. Others had families in Akplabanya.
Did you move from a different	No= 12(19%)	A higher percentage of participants moved

place to Akplabanya? why?	Yes, other reasons= 23(38%) Yes, Climate related reasons= 26(43%)	from and returned to Akplabanya before 2015 due to low fish catch and economic hardship

2.3.1 social-ecological system changes in Akplabanya

I found five (5) major ways in which Akplabanya had and is experiencing coastal social-ecological system changes. My findings are listed as themes and subthemes for O1 in Table 2.2. These themes are 'coastal climate change', 'resource change', 'biodiversity loss', 'pollution', and 'population change'. Under the coastal climate change theme, I found four subthemes: sea-level rise, changing patterns of tidal surges, changing patterns of coastal erosion, and changing patterns of rainfall. I further found the frequency of quotes supporting these sub themes of coastal climate change: Sea-level rise was supported by forty-two (n=42) quotes from participant responses, Changing Patterns of Tidal surges by thirty-five (n=35), Changing Patterns of coastal erosion by fifty-five (n=55), and Changing patterns of rainfall by fourteen (n= 14). The Coastal climate change theme can be linked with the photos 'e' and 'f' in Fig 2.4. Under the Resource change theme, I found three subthemes: Changes in the sea, Land use change, and Freshwater change. Changes in the sea were supported by forty-one (n=41) quotes from participant responses, Land use change by 48, and Freshwater change by fifty-six (n=56) quotes. The resource change theme can be linked with the photos 'a' and 'b' in Figure 2.4.

Under the Biodiversity loss theme, I found two subthemes: vegetation and farming activities, and Livestock change. I found the frequency of quotes supporting these sub themes of Biodiversity loss: Vegetation and Farming activities were supported by fifty-five (n=55), while Livestock change was supported by thirty (n=30) quotes. Under the Pollution theme, I found unsustainable practices subtheme. The frequency of quotes from participants supporting unsustainable practices was twenty-nine (n=29). Under the Population change theme, I found one subtheme: Increasing population. Increasing population was supported by twenty-seven (n=27) quotes from participant responses. The biodiversity loss theme can be linked with photos 'd' and 'g' and the pollution theme can be linked with photo 'c' in Figure 2.4.

Table 2.3: Responses from semi-structured interviews (n=61) that support the themes and subthemes for Objective 1.

Themes and subthemes	**Changes in human-environment interactions (O1)**	**Quotes from participant responses**	**No. of participants** *(The total frequency of responses that support the themes and subthemes)*
Coastal climate change:			
Sea-level rise	Akplabanya has lost fruit trees like coconut trees at the beach and grasslands that existed between the community and the sea where kids used them as playgrounds.	*"Physically I have observed that our sea level was physically far away back then but it's so close now" (SSI respondent 02) "Fruit trees like coconut trees no longer exists, grass as playground no longer exists, and it all started after the tidal waves continue to come and come and come" (SSI respondent 03)*	42
Changing patterns of tidal /storm surges	Tidal surges have caused the loss of time, money, and education. The tidal surge highly affects the children of the community and introduces a pattern where other economic livelihoods apart from fishing exist for short periods and then collapse due to the recurrent tidal surges.	*"My boat, my fishing canoe or boat was scattered apart when we are flooded some time ago, in fact I also lost an outboard motor. I've lost all these things. the outboard motor today is costing about 40,000 Ghana cedis ($3,300) and the machine the canoe too about 70,000 Ghana cedis ($5,700) that's a used one that you have to buy, and so I lost about over a 100,000 plus ($9,000)." (SSI respondent 58)*	35
Changing patterns of coastal erosion	The coast of Akplabanya has been eroding as tidal surge take bites off their land. The sea also carries eroded sand from the coast to everywhere in the community filling all water channels.	*"The sand on the beach used to be plenty but the sea has taken it all back into the sea" "The more the community gets flooded by tidal waves, the more beach sand is carried and deposited into the community. so, the little rainfall, the community get flooded" (SSI respondent 27)*	55
Changing patterns of rainfall	The fishers of Akplabanya have lost their skill of predicting fishing periods from observing rainfall patterns. Floods from unexpected rains prevent fishmongers from processing fish-catch from fishers	*"In terms of rainfall and sunshine, I know some seasons have more rainfall and others have more sunshine, and I have experienced changes where seasons with fewer rainfall now have more and seasons with less sunshine are now warmer." (SSI respondent 02)*	19
Resource change:			
Changes in the sea – fishing and quantity of fishes	Participants responded that their fishing livelihood had previously declined which led to	*"I have moved, I travelled to Senegal in the year 2000. I went to sea (to fish there). I came back In the year 2013. I left for*	41

	their relocation to other places. Though the fishers returned, they have to compete with big trawlers and that competition has led to fishers unable to catch certain species.	*Senegal because the fishing here was low (at that time)"* (SSI respondent 38) *"Over the period, we use to get a lot of fish on our coast here. We don't go deep into the sea we don't go far before we get the fish. But now we have to go deep into the sea very far before we get the fishes because, China trawlers and those big big trawlers happens to be fishing on the sea and have prevented the fish from coming down to our coast" (SSI respondent 59)*	
Land use change – nature, size, and buildings	Participants narrated how the community has lost land mass, homes and infrastructure like networks of electricity poles and water pipes. Participants further responded that the salt content in the land has reduced the quality of their buildings.	*"The land (size) keep decreasing (reducing) because of the sea that is eroding. We have a lot of land entering the sea. The land is also very salty that we cannot even grow anything there" (SSI respondent 61)*	48
Freshwater change – rivers, wells	Participants narrated how recurring floods from tidal surges had impacted their rivers which has led to the loss of freshwater bodies.	*"At the age of 18 years (about 27 years ago), Akplaba was so big that not everyone was allowed to go near it, but because the sea keeps pushing us back, and the consistent floods from tidal waves keep depositing sand in Akplaba, the river has lost its worth" (SSI respondent 09)* *"There used to be a river called Sangleteh (A river that used to exist) between the community and the sea. The Sangleteh river prevented Akplabanya from flooding but now, the sea has swallowed Sanglateh, and it is no more" (SSI respondent 13)*	56
Biodiversity loss:			
Vegetation and Farming activities	Participants narrated the loss of vegetative cover like coconut and neem trees, and tall grasses on the coast. Participants were particular about the loss of specific type of grass previously used by fishmongers to smoke fish as a result of tidal surges. Furthermore, the recurrent floods in Akplabanya narrated by participants caused loss of soil fertility, halted farming activities, and has led to the loss of farm produce for subsistence and commercial purposes.	*"We had to cross the Akplaba river to the bank behind the river. Behind the bank of the Akplaba river is where we farm. So, we cross the river and go and farm, uproot cassava, peel cassava there, dry cassava for kokonte, then we have to cross back to Akplabanya before we come home. These things today are not there. We won't see these things again, those days we don't buy food, we get food from our farms but today, farming has ceased completely in Akplabanya" (SSI respondent 16)* *"Fruit trees like coconut trees no longer exists, grass as playground no longer exists, and it all started after the tidal waves continue to come and come and come" (SSI respondent 02)*	55

Livestock change – the alternative source of food and livelihood	Participants responded on the reduction in the quality of livestock as a result of vegetation loss. Further, participants narrated the loss of livestock species like cattle. However, participants also mentioned that the current number of livestock is more compared to previous years as population is increasing.	*"Animals are not able to get the grass field to feed on because the floods take away everything. So, you realize that the place becomes grassless. I have about 30 sheep, today they are all dead and I have only two sheep left. When they are on a free range, they can't find anywhere to graze and they have to come back, some go to feed on other poisonous things and then killing them, and so this is another challenge, of the sea-level rise and then the tidal waves flooding our place" (SSI respondent 08)* *"The number of animals we have today are more than 30 years ago. Because of population increase, the more people are rearing animals" (SSI respondent 50)*	30
Pollution:			
Unsustainable practices	Participants narrated the community's practice of dumping refuse in the Akplaba river as a means to create space for building because they kept losing land size to the sea.	*"Because the sea keeps pushing us forward and forward, we are forced to dump refuse into the Akplaba river so we can make space to continue with our fish smoking business. Even here we are seated, those days, the Akplaba river was here" (SSI respondent 09)*	29
Population change:			
Increasing population	Participants explained how population has increased and causing strain on resources fish and land	*"With population growth, we have become so populated and I realized that, increasing number of fishing boats and canoes on our shore here " (SSI respondent 23)*	27

Figure 2.4: A collage of images that support the findings for Objective 1 in Table 2.3. a) Changes in fishing experience b) Diseases and health issues c) Unsustainable pollution d) Livestock pattern change e) Loss of building and assets f) Sea-level rise - loss of land to sea g) Loss of farming activities (Photos by Brandy).

Coastal climate change, characterized by sea-level rise, changing tidal patterns, coastal erosion, and erratic rainfall, has dramatically reshaped physical and social landscape of Akplabanya. The recurrent flooding of the sea has led to the loss of vital resources, including fruit trees and grasslands, impacting the community's traditional way of life of mostly fishers and fishmongers. Additionally, resource changes, such as declining fish stocks, shifts in land use, and freshwater loss, have created significant livelihood dynamics and challenges. Respondents narrated low fish-catch before the introduction of light fishing. However, due to increasing population and competition between Akplabanya fishers and international fishing trawlers. The loss of biodiversity, driven by the depletion of vegetation and disruptions in traditional practices like fish smoking, has impacted food security and led the community to depend on market centers.

The five main themes that emerged from perceived social-ecological system changes in Akplabanya have been summarized in Figure 2.5. The figure shows that Akplabanya previously had food from their farmlands, had rivers and a well for domestic use and drinking, had a high number of livestock including cattle, neem trees, grass and herbs for healing, rich Indigenous cultural practices, and clay structures. However, the figure also shows that Akplabanya now buys food from local markets, buys water from the government for domestic use, has no rivers, no well, and only fish in the sea and is now experiencing decline in fish catch. The figure further shows that Akplabanya now purchases expensive healthcare from government hospitals, replaced their clay structures with block buildings and has unmanaged waste throughout the community.

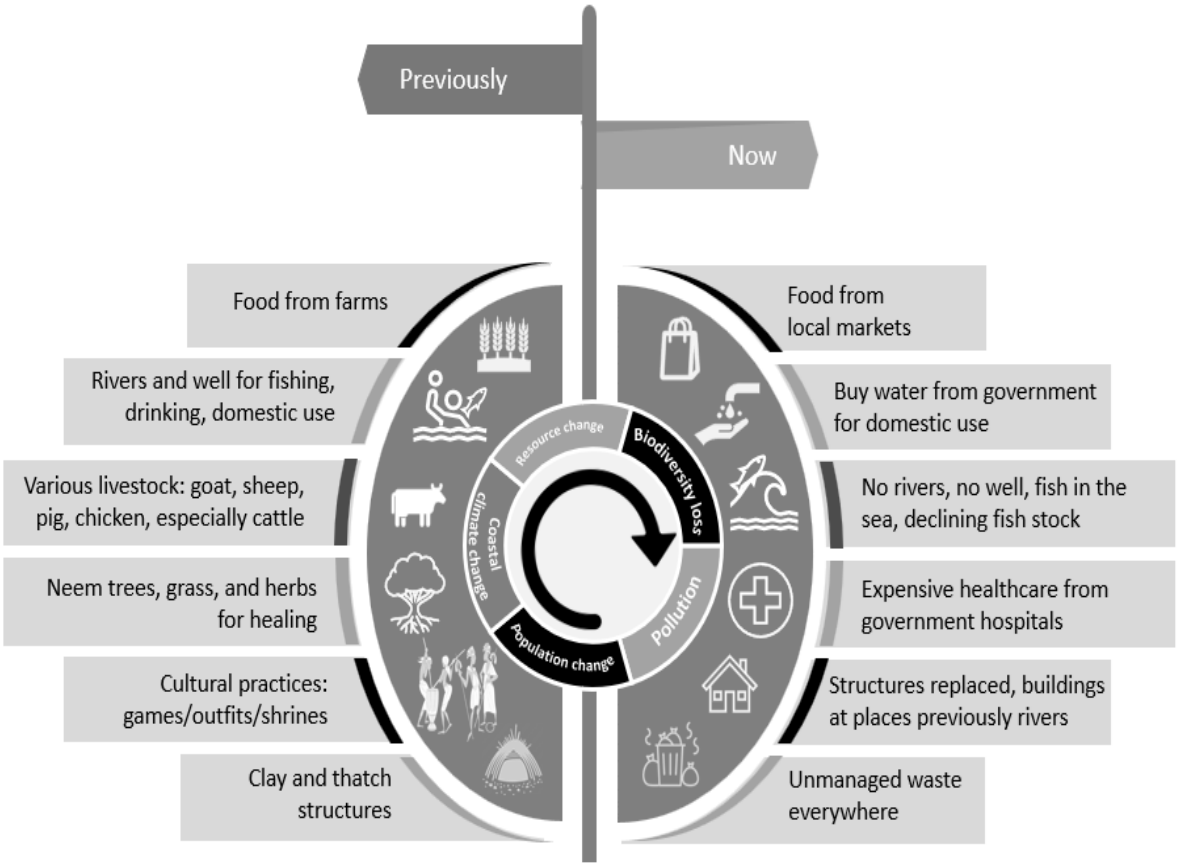

Figure 2.5: Summary of the five major themes found to address Objective 1 in Akplabanya.

2.3.2 Key adaptation responses to the social-ecological system changes in Akplabanya

This section emphasizes the interconnectedness of the themes used in the conceptual framework of this study. It describes how Akplabanya coped, transformed, and adapt to become resilient or vulnerable.

2.3.2.1 *Place*

According to Ford et al. (2020), the conditions of livelihood and social, cultural, economic, demographic, and political forces acting on different spatial-temporal scales will define the factors impacting resilience to environmental change (Béné et al., 2014; Brown, 2015). These scales can be a place that operates to influence resilience to environment change (Cinner & Barnes, 2019; Ford et al., 2020; Galappaththi et al., 2019). I found that respondents described "place" as their identity and livelihoods with sub themes like fishing, and land, where fishing is their primary sense of place. I found out that due to respondents' fear of loss of their connection to the sea, fishers began to incorporate a technology adopted from big trawlers of Tema in 2007. The technology the fishers incorporated is light fishing. In light fishing, fishers attract fish with a light bulb with the intention to catch it. The incorporation of this technology as a response to low-fish-catch transformed daily fishing time in the community from mornings to evenings with the exception of fishing holidays. The result of the incorporation of light fishing technology boosted fish-catch in Akplabanya. Boosted fish-catch led to the return of fishers who had left the Akplabanya for better fishing opportunities in other communities.

Further, I found that sea fishing, and land are linked where one category is dependent on the other but not vice versa. The community quickly adopted coping methods like creating water channels on their land to prevent their fishing livelihood from being affected by recurrent flooding. The land of Akplabanya is where the family of fishers reside, where children are educated, where all family gods reside, where fishers build, create, and maintain their canoes, boats, and fishing nets as well as where fish are distributed, processed, and traded. These findings showed that land is the secondary sense of place for Akplabanya community. This is because the loss of land size through tidal surges, sea-level rise, and coastal erosion did not drive some people of Akplabanya out of the community. However, without fishing activity in Akplabanya, people migrated out of the community to other fishing communities. In contrast, though light fishing led to the return of fishers who left, and boomed fishing for a while, it introduced maladaptation. Barnett & O'Neill (2013, p.88) defined maladaptation as "actions taken to adapt to climate change that inadvertently increase the vulnerability of other systems, sectors, or social groups". According to the perceptions of respondents, fishers have to compete with international fishing trawlers. Quotes to support place include;

"With this technology (light fishing), canoes of the various households have multiplied in Akplabanya, and some fishers have been able to see their children through tertiary education." (SSI Participant 19)

"As a fisherman, I traveled to Cameroun to do fishing, I lived there for about 2 and half years and returned to Akplabanya. I left here in 1997 for Cameroun because the work I was doing here because the fishing work in Akplabanya wasn't getting better at that time." (SSI Participant 13)

"We have become overpopulated and so the trawlers too have blocked the big big fishes from coming close to our coast. Those days when the trollers were not there, we would go to sea and come back with very heavy fishes." (SSI Participant 14)

2.3.2.2 *Agency*

The conceptual framing explains agency as the capacity of individuals or groups to act independently and make their own free choices, which in turn affects resilience to environmental changes (Ford et al., 2020; Cinner & Barnes, 2019; Brown & Westaway, 2011). I found four sub themes related to individual agency in response to environmental change: conservation, recycling, food, and health. Regarding food and health, I found that there are small-scale supermarkets, pharmacies, and local health centers in response to the loss of farmlands and herbs from neem (*Azadirachta indica*) and coconut trees. Though the community uses pharmacies and local health centers for diagnosis or medications, they purchase health services either at the administrative center or in the next big town. I also found that the small-scale supermarkets replaced lost farm produce like coconut, cassava, okra, peppers, and tilapia caught from the Akplaba river. I observed barricades around small trees and tied bags full of used plastic bottles in the community. The barricades were the community's coping response to vegetation loss caused by recurrent floods from tidal surges and coastal erosion. In my observations, I found that the collection of used plastic bottles was a response to pollution in the community. However, though practiced by a few individuals who sell plastic bottles to recycling companies in exchange for money, as a help to reduce pollution. Quotes to support agency include;

"Formerly, there used to be some foods (from farmlands), today we don't have them, but we buy them from different places to come and eat." (SSI respondent 10)

"We used to have fruit trees like coconuts, but we no longer do as they all died due to saltwater intrusion into the soil. Fruits are so expensive this time around as well as food, so, to spend 10 gh cedis to buy fruit like mongo, I would rather use the money to buy a bowl of gari which though less nutritious, can fill me up. This is another reason why we fall sick easily." (SSI respondent 04)

2.3.2.3 Collective Action

The conceptual framework used in this study defined collective action as the efforts made by groups within Indigenous communities to achieve common goals, particularly in managing resources and responding to environmental changes (Ford et al., 2020; Galappaththi et al., 2019). This theme is concerned with how Akplabanya protects their community and current culture, and adaptation to their ongoing environmental changes. I identified three sub themes related to collective action which are comfortability, replacement, and sustainability. Under the Comfortability subtheme, I found two collective actions: collective action in the creation of water channels by community members when flooded by tidal surges. Akplabanya is flooded by tidal surges multiple times every year, and government agencies like the National Disaster Management Organization (NADMO) are inconsistent with their visits during floods. Therefore, community members resort to creating water channels that redirect the flood water back to the sea or the Songor Lagoon as an adaptation response to environmental change. The creation of water channels gives the community some form of comfort to carry on their daily activities. Another collective is the use of old flour bags as shade while fishers mend their net at the beach.

Apart from the comfortability subtheme, I also identified the subthemes of replacement and Sustainability. Under the replacement subtheme, I observed fishmongers smoking their fish with roots of trees purchased from other communities and dried sugarcane peels. This collective is a coping response of fishmongers to loss of vegetation. Previously, fishmongers used dried tree branches and green leaves to smoke fish which gave their fish a preferred color, taste, and good smell that aligns with high market prices. Therefore, the trees purchased from other communities and dried sugarcane peels replaced the resources they had from vegetation four decades ago. Again, I found collective action under the sustainability subtheme. I observed the practice of the free-range system for livestock in the community. The Humane Farm Animal Care (HFAC) program defines a free-range system in the context of poultry as having at least 2 square feet per bird and must be outdoors, weather permitting, for a minimum of 6 hours per day (Certified Humane, 2014). The free-range system was the community's transformative response to the loss of the main food for their livestock from farm produce like cassava before 1982. Quotes to support collective action include;

"*I have about 30 sheep…they are not able to get the grass field to feed on…so they are on a free range." SSI Respondent 08*

"Anytime we are flooded, we have to create water channels and dig gutters for the waters to flow back, that's the only thing that we do before we can become free." SSI Respondent 21

2.3.2.4 Institutions

The conceptual framework used in this study defined institutions as the formal and informal norms, rules, and organizations that stem from social interactions and guide behavior within and between Indigenous communities and government (Ford et al., 2020; Ostrom, 2000; Poteete & Ostrom, 2008). I found four sub themes linked to institutions. They are previous projects, internal help, reactive strategies, and proactive strategies. Under the subtheme of previous projects, I found out that people of Akplabanya had received solutions from the government regarding floods from tidal surges in 1997 and 2013. The government through the District Chief Executive (DCE), was in charge of both projects: 1) an uncompleted small-sized defense in 1997 that was later destroyed by recurrent tidal surges after a year, and 2) the sea defense that is yet to reach the shores of Akplabanya. The DCE began both projects however stopped midway after government change. The government's adaptive strategies through the DCE are the response to sea-level rise, recurrent floods, and coastal erosion in Akplabanya and its neighboring coastal communities in the Ada West district.

Apart from the previous project's subtheme, I found internal help and reactive strategies subthemes. Under the internal help subtheme, I found that the village chief and his cabinet organized the community water channels at the east end and west-end of the community when government agencies failed to come to their aid. This institutional move by the village chief is the coping response to floods from tidal surges that mostly flood the community at dawn. Under the reactive strategies subtheme, I identified two institutions: local institutions in Akplabanya and government agencies. I found that the chief fisherman in coordination with the Landing Beach Committee, Canoe Fishermen's Association, and Premix Fuel Committee put together funds to support fishers who are affected by strong tidal surges. These would often be fishers whose canoes, fishing nets, outboard motors, boats, generators, and other materials used in fishing, had been destroyed during strong tidal surges. Though this adaptive response of local institutions is reactive, it aids fishers to bounce back to their livelihoods, making them more resilient.

Under the sub theme of reactive strategies, I further learned that the government worked through National disaster management organization (NADMO) in Akplabanya. NADMO is responsible

for managing natural disasters like floods from tidal surges in Ghana. They provide the community with some basic items like rice, mattresses, and used clothing for the Unit Committee to distribute among households. This coping strategy by NADMO is their response to the loss of basic items during floods by tidal surges. This reduces vulnerability of affected households. While the institutional response of NADMO aids Akplabanya, it introduces maladaptation. The distribution of basic items by the Unit Committee to affected households always resulted in conflict. This is because the basic items are mostly insufficient for the affected households. Again, I learned that the government worked through Fisheries Commission to implement a two-month national fishing holiday for fish replenishment in 2019. This policy is the government's adaptation response to low fish-catch along the coast of Ghana. I found that the policy has led to an increase in fish-catch in Akplabanya, increasing their resilience to issues on fish-catch. Quotes to support institution include;

"NADMO last came in April this year (2022) with few clothing and beds. Sometimes when the community is flooded, NADMO officials come in with their rubber safety boots to assess the extent of the damage and leave" (SSI respondent 03)

Other times NADMO came to give us blankets and sleeping mattresses and about 20-30 people were given a bag of rice" (SSI respondent 17)

"About two decades ago (2002), we cried out to the government at that time to come to our aid concerning the recurrent floods from tidal surges, so the government brought in huge blocks of stones and deposited them at the shoreline but got destroyed after a year. The project was incomplete because the government changed power and the focus on the community shifted. After that, about a decade ago (2012), the government started building sea defense from Ada Foah, the capital town of all the Ada District to Totope, a village along the coast but the project stopped when power changed hands again" (FGD 2)

I explored the dynamics of roles within Akplabanya community. I found roles in the community as well as the dynamics of interactions between the community and government agencies in responding to perceived social-ecological system changes. I made these dynamics into structures using cylindric and arrow shapes in Microsoft Word. These structures are Figure 2.5, Figure 2.6 and Figure 2.7. Figure 2.5 represents Akplabanya Youth Connect, who are predominantly males, charged with creation of water channels following floods from tidal surges. The Landing Beach Committee, Canoe Fishermen's Association, and Premix Fuel Committee are responsible for the funds needed for a temporal solution for the floods: Unit Committee is responsible for contacting government institutions to come to their aid; and Fishmongers Association is responsible for

reporting on the extent of damages on fish processing caused by the floods. These committees vertically answer to both the chief of the Akplabanya and the chief fisherman, and horizontally coordinate with one another to share information.

Though internal dynamics play major roles in responses to perceived changes, external dynamics with government institutions play contributing roles. Due to the division of power between the chief of the Akplabanya and the chief fisherman, there are two structures inter-twined. The chief fisherman focuses on fishers who may have lost their fishing gear due to high tides on the sea, and coordinates with members of the Canoe Fishermen's Association, Fishmongers Association, and Premise Fuel committee to provide money incentives to casualties as shown in Fig 2.6. However, both chiefs interact with government agencies differently. Contrastingly, government institutions interact with Akplabanya community using a top-bottom approach. Figure 2.7 represents the characteristics of interactions between these two main institutions are the vertical and horizontal linkages within their domain. The government institutions work in a vertical workflow where decisions are made at the top ministerial level to the District Chief Executive, then to the Municipal Assembly, where they implement the decisions through the Unit committee in the community without consistent feedback. However, the local committees of Akplabanya work in a horizontal workflow where the Village chief consults with representatives from each established committee in the community.

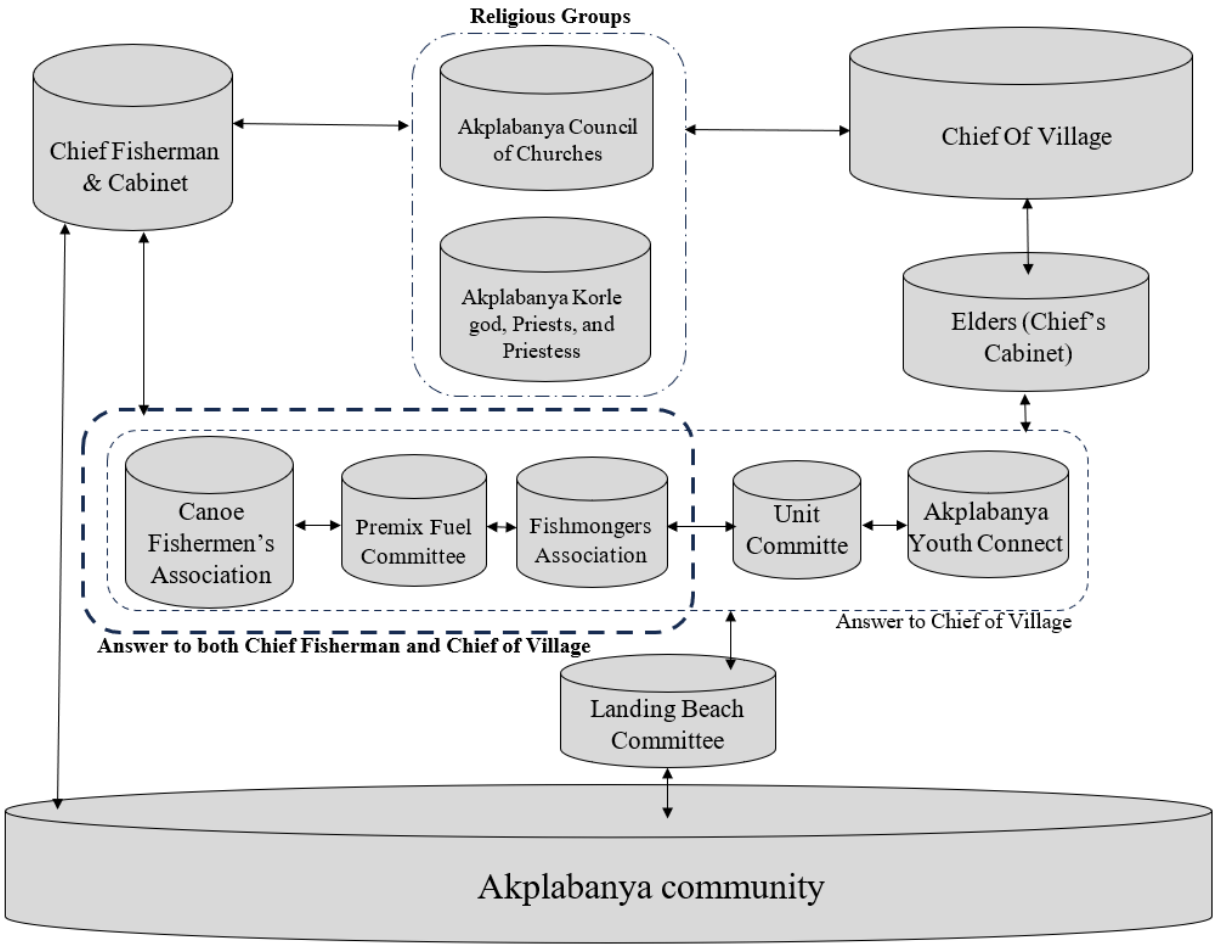

Figure 2.6: Dynamic roles in Akplabanya community to respond to perceived social-ecological system changes created in Microsoft Word.

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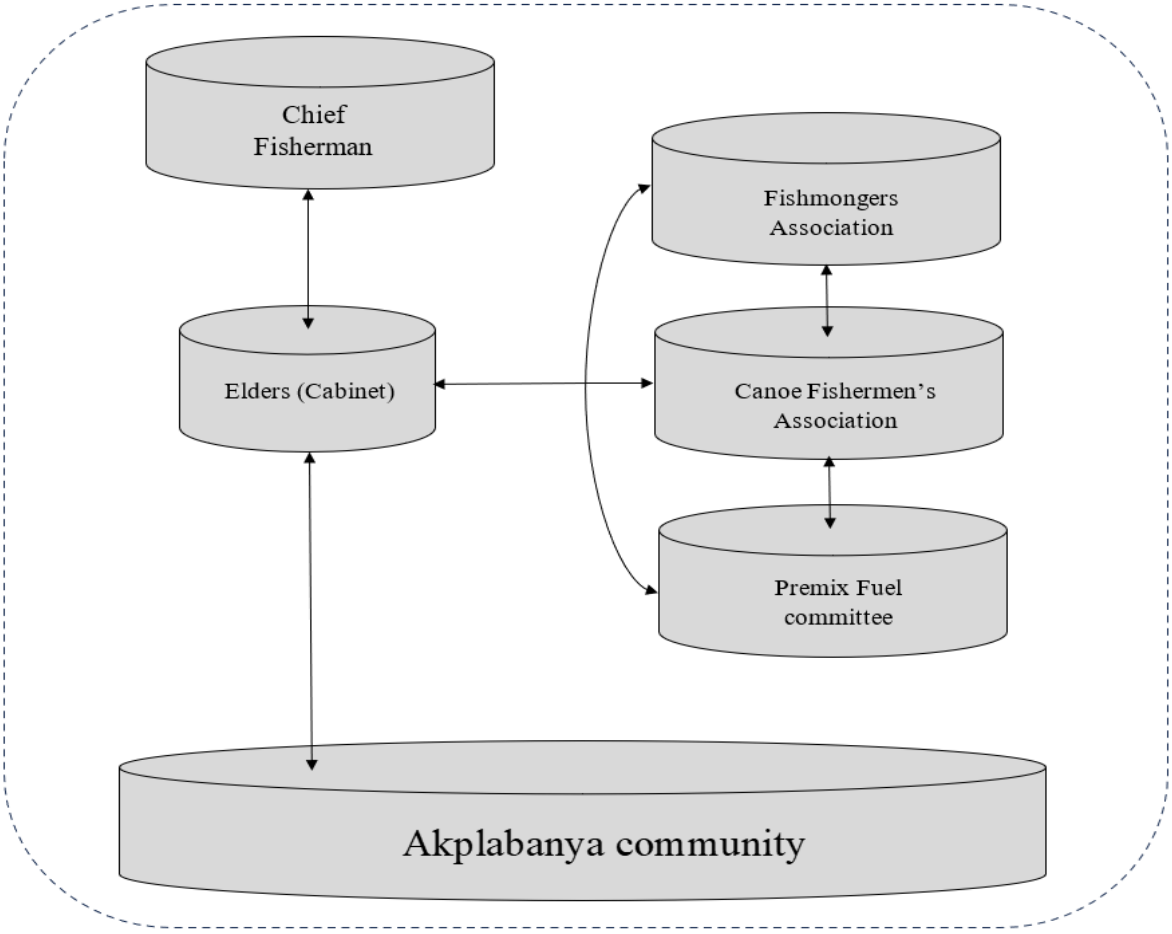

Figure 2.7: Dynamics of roles between Chief fisherman and three committees to respond to perceived social-ecological system changes in Akplabanya created in Microsoft Word.

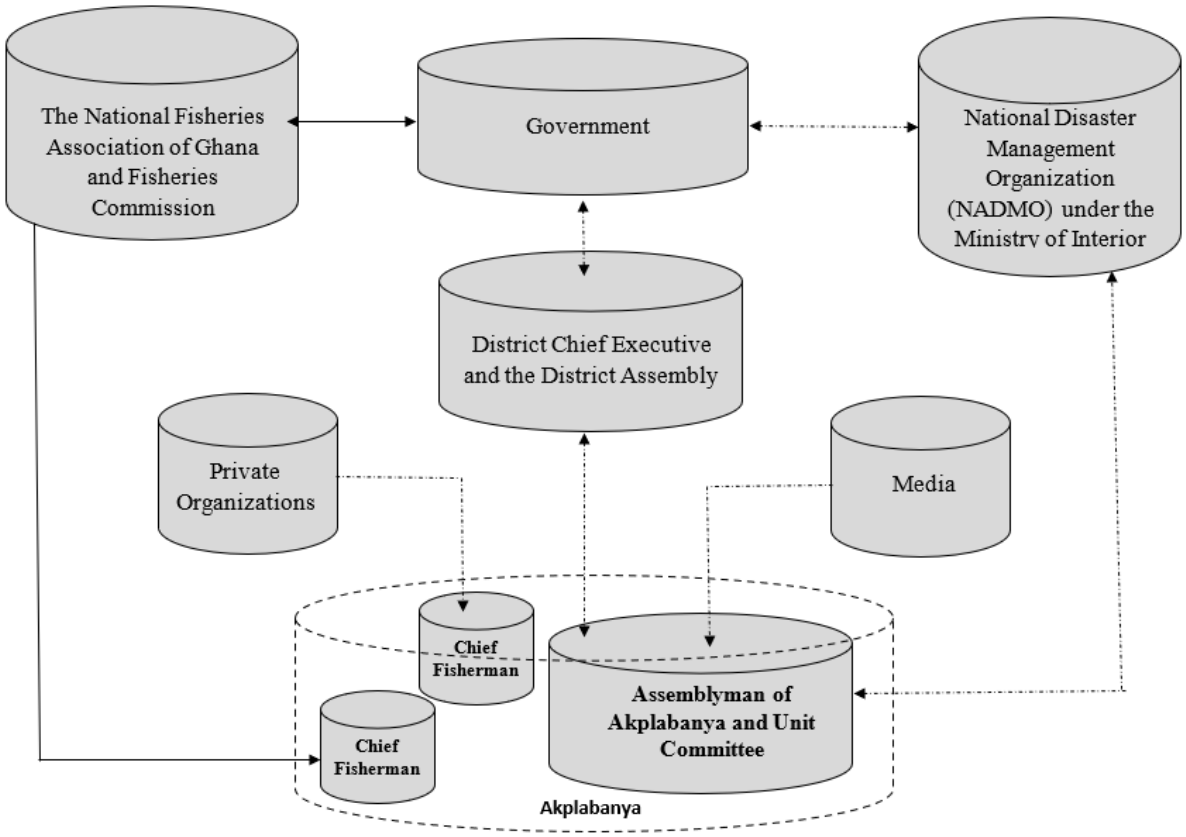

Figure 2.8: The vertical Structure of Government institutions in connection to Akplabanya to respond to perceived social-ecological system changes created in Microsoft Word

Note: The dotted connections is made when Akplabanya is floods, and the straight connections occur during decision making about coastal fisheries.

2.3.2.5 Coastal Indigenous Knowledge

The conceptual framework used in this study defined Indigenous knowledge as unique identity to a given culture or society, which includes the practices, understandings, and insights gained over time, often in the context of managing local resources and environmental change (Ford et al., 2020; UNESCO, 2023). In the case of Akplabanya, Indigenous knowledge is related to the coast. I found that the community is losing its Indigenous knowledge. Specifically, two sub themes of responses related to coastal Indigenous knowledge in Akplabanya were identified. These subthemes are medicine and architecture. Under the medicine subtheme, I found that the community had transformed from traditional herbal medicine to modern healthcare. This transformation is the community's response to their depleted vegetation (Table 3.2) and the loss of older generation who

held Indigenous knowledge of traditional herbal medicine. I found out that the transformation is characterized by fewer households growing important herbs for local remedies and increased visits to hospitals and clinics to receive modern healthcare.

Under the architecture subtheme, I found out that the community switched from building structures made with clay and thatch to block buildings. I observed that majority of community households were constructed of block buildings. This transformation is community's response to recurrent floods from tidal surges that caused households to lose their homes. However, changing architecture introduced a maladaptation in the community's transformative response. The block buildings in community were built with beach sand. I observed these block buildings wearing out. This was because of high salt content in the soil. After transformation from buildings made with clay and thatch to block buildings, the community put in coping mechanisms like replastering and painting to maintain their buildings. Quotes to support coastal Indigenous Knowledge include;

"we have been winning the sand to mound blocks and build our houses." (SSI respondent 14)

"fresh leaves of the neem tree (azadirachta indica) are used to manage and cure fever." (KII Participant 28)

2.3.2.6 Learning

The conceptual framing explains learning as being able to understand and use new information when things change, figuring out what to do, and looking at problems in different ways (Cinner & Barnes, 2019; Ford et al., 2020). I found two sub themes related to Learning in Akplabanya. They are awareness and technology. Under awareness, I found that community members of Akplabanya understood what climate change meant. This was due to the community's previous meetings with officials from government agencies like NADMO. Such awareness is an adaptation response to sea-level rise, recurrent flooding, and coastal erosion due to the changing environment on the coast of Akplabanya. Awareness can present learning opportunities for local adaptation responses. Under the technology subtheme, I observed fishers with mobile phones used for sharing information on fishing among themselves. In addition to mobile phones, I found that fishers of Akplabanya had purchased and learned to use Global Positioning System (GPS) devices to aid navigation at night. I found that the use of technology is fishers' response to low fish-catch in the community. Both sub themes related to learning have increased resilience to climate change and low fish-catch in Akplabanya. Quotes to learning include;

"So, we were the first people to get GPS, which have been given us directions. And sometimes when we have fog on the sea, it gives us directions to where we are going, and then sometimes it direct us to where the fishes are, and then we go and cast it there and we catch fish, so I realize that it was we who brought it, and we realize that it is helping us so people are now buying it." (SSI Participant 61)

"Officials from government agencies when they come to the community following floods from tidal surges, they would say climate change has caused the ice abroad to melt so the sea level is rising. That is how we know the climate is changing" (SSI Participant 15)

2.4 Discussion

This study aimed to understand perceived social-ecological system changes and key adaptation responses in Akplabanya coastal community, Ada West, Ghana. The study is built on two months of empirical data collection in Ghana using mixed methods of participant observation, semi-structured interviews, key informant interviews, and focus group discussions.

The six themes of responses to perceived social-ecological system changes can be likened to the basin of attraction as shown in figure 2.9. In a dynamical system, such as fisheries system in Akplabanya, different states represent different configurations or conditions of the system (Westley et al., 2013; Gunderson & Holling, 2002). In the basin of attraction, initial conditions eventually lead the system to a particular stable state. Applying the basin of attraction to the fisheries system in Akplabanya, the critical point is that while coping, transformative, and adaptive responses can enhance resilience in the short and long term (Brown, 2015), they may also have unintended consequences. Some responses may inadvertently push the system toward less desirable states, resembling the edges or boundaries of the basin of attraction (Petraitis, 2013). This highlights the need for careful planning and monitoring of responses to ensure they do not lead to maladaptation or shift the system into unstable or undesirable states. Effective governance, support from external institutions, and the preservation of local knowledge can help navigate these complexities and keep the system within a desirable basin of attraction (Anderies et al., 2013).

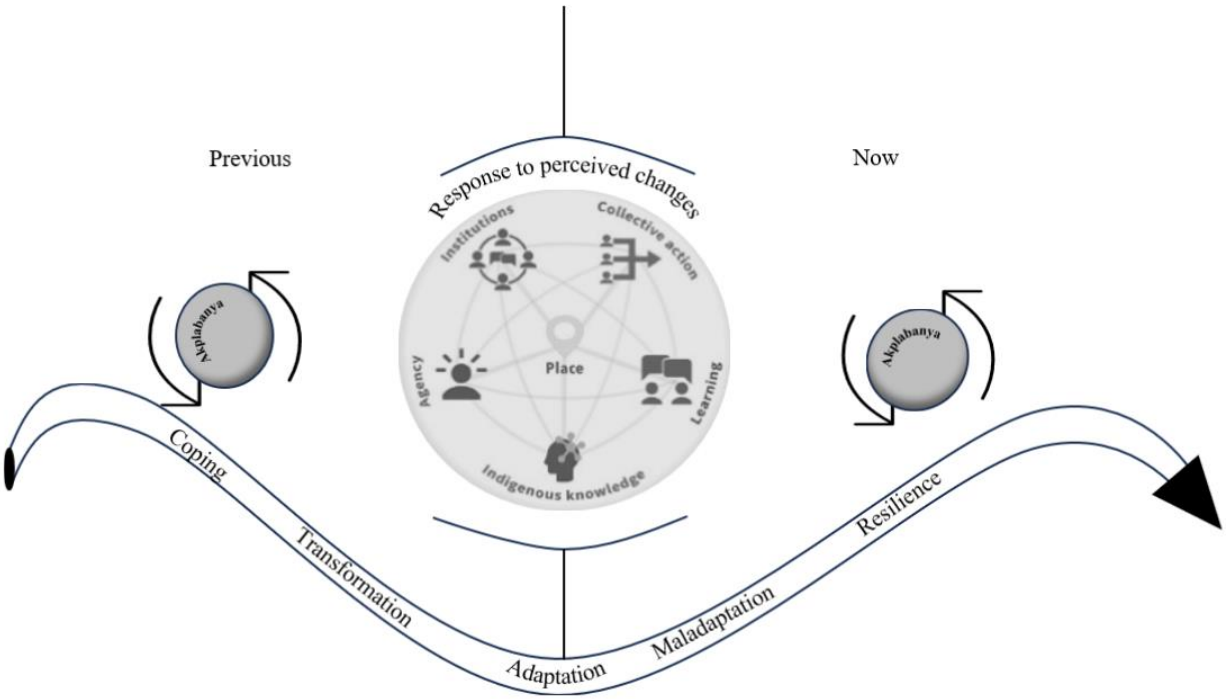

Figure 2.9: Summary of coping, transformation, and adaptation responses that have to be resilient and maladaptation (Ford et al., 2020; p539).

In the results, there were various instances where respondents indicated coping, transformative and adaptive abilities which are depicted in Figure 2.9. Coping responses in Akplabanya, such as the creation of water channels to deal with recurrent flooding, can be seen as strategies aimed at maintaining resilience within the community (Babson, 2020). Such coping mechanisms help the community endure immediate challenges from floods. Transformative responses involve significant changes in the way the community operates, such as adopting new technologies like light fishing to boost fish catches. These transformations may temporarily move the community into a different state that is more resilient to certain social-ecological system changes. However, they may also introduce unintended maladaptation (Janssen et al., 2007; Pelling, 2010), such as increased competition after the adoption of new fishing methods, which has pushed the system toward less desirable outcomes like low fish-catch. Adaptive responses are those that aim to adjust to changing conditions while preserving the core values and functions of the system (Folke et al., 2003; Nelson et al., 2007). For example, the use of technology like GPS devices for navigation can enhance the community's ability to adapt to changing fishing conditions (Malakar et al., 2019). These adaptive responses can be used to guide their fisheries system toward a more desirable and stable state within the basin of attraction, increasing resilience in the long term.

The results of O1 are aligned with literature. Globally, some Indigenous coastal communities have demonstrated more remarkable resilience and adaptation than others in climate and resource change. For instance, in the Maldives, where the threat of rising sea levels is great, coastal communities have taken proactive measures (Brown et al., 2019; Gagain, 2012). They've constructed artificial islands and elevated infrastructure to safeguard against inundation, showcasing their determination to adapt to the challenges posed by climate change (Brown et al., 2019). However, in contrast, some coastal communities in Ghana, particularly vulnerable areas in Akosua village, Winneba, have been slower to respond to coastal social-ecological system changes impacted by climate change which is similar to Akplabanya. Akosua faces unexpected rains resulting in losses of half-dried fish which is a major problem affecting fish processing (Koomson et al., 2020). Furthermore, in the Mekong Delta, Vietnam, challenges persist due to changing water resources as shown in the work of Ha et al. (2018) which is similar to the findings in Akplabanya on their loss of freshwater systems. Altered river flow and salinity intrusion in the Mekong Delta have impacted agriculture and water quality (Xiao et al., 2021). Limited infrastructure and resources have hindered the region's ability to manage these resource changes effectively, showing the complex nature of coastal social-ecological system change impacted by climate change (Renaud et al., 2015).

The findings on biodiversity loss and pollution show the environmental challenges faced by Akplabanya, Ghana. Furthermore, recurrent coastal floods have led to the loss of vegetation and farmlands due to soil infertility which is similar to some parts of Bangladesh's coastal regions (Khanom, 2016). In Bangladesh, frequent riverbank erosion and saline water intrusion have resulted in soil degradation and agricultural land loss, impacting local communities (Ullah & Rahman, 2014). Meanwhile, like Akplabanya, some communities have resorted to pollution in rivers with solid waste as an unconventional adaptive response to mitigate land loss. For instance, in certain regions of Southeast Asia, like parts of Indonesia and Bangladesh, communities facing similar land loss challenges have employed practices like dumping waste into rivers to create artificial land or embankments as a means of protection from rising sea levels and erosion (DasGupta & Shaw, 2017; Eguchi et al., 2013). This adaptive strategy in Akplabanya reflects the community's resilience to safeguard their homes and livelihoods in the face of environmental challenges, drawing parallels with these Southeast Asian cases. However, it is crucial to recognize the consequences of such pollution like breeding grounds for mosquitos and other insects

responsible for diseases like malaria. In the Sundarbans of Bangladesh and India, similar practices has led to adverse impacts on local fisheries and wildlife (Burman et al., 2019; Hoq, 2014).

The outcomes of O2 can be placed within the wider context of existing literature. This study identified key adaptation responses to the coastal social-ecological system changes in Akplabanya, Ghana. I found place-based and agency elements in Akplabanya, Ghana, in their responses to coastal social-ecological system changes. Facing the challenge of shifting their fishing practices from the traditional coastal morning fishing to evening fishing, Akplabanya's residents show their determination to retain their sense of place in the sea. This transformation resonates with experiences in other coastal communities worldwide, such as those in Japan, where traditional fishing practices have adapted to incorporate modern technology like GPS navigation and sonar systems, allowing them to maintain their deep-rooted connection to the sea (Hatanaka et al., 2007; Natsir et al., 2020). The deep-rooted connection within Akplabanya is evident in their agency. Faced with the loss of farmlands and traditional herbal resources, the community has demonstrated collective agency by introducing small-scale supermarkets, pharmacies, and local health centers. This adaptive approach to diversifying livelihoods and access to essential services is reminiscent of initiatives undertaken by coastal communities in India, where the introduction of small-scale enterprises like eco-tourism and handicraft businesses has provided alternative sources of income in the face of environmental changes (Hzami et al., 2021; Saad, 2021).

Collective and institution-based actions emerged as ways Akplabanya community in Ghana has responded to social-ecological system changes. The community has come together to tackle recurring floods triggered by climate change by collectively constructing water channels to redirect floodwater, safeguarding their homes and livelihoods. This mirrors the collective action taken by communities in Bangladesh, where the regular threat of flooding has prompted locals to organize build, and maintain embankments and levees, demonstrating the power of community-driven adaptation (Dewan, 2022; Ensor & Berger, 2009). Furthermore, local institutions have played a supportive role by assisting fishers during tidal surges triggered by strong storms from climate change. Though local institutions have been supportive in Akplabanya, their efforts do not mirror the actions of community-based organizations in the Philippines. Local institutions in the Philippines have established early warning systems and disaster preparedness plans to protect fishermen and coastal communities from typhoons and extreme weather events (Iuchi et al., 2019). In Akplabanya, I found that government work through NADMO to provide necessities for the

community after flooding events, reflecting similar disaster relief efforts undertaken by government agencies in regions like the United States in the aftermath of hurricanes (Bullock et al., 2018).

Furthermore, local institutions have played a supportive role by assisting fishers during tidal surges triggered by strong storms from climate change. Though local institutions have been supportive in Akplabanya, their efforts do not mirror actions of community-based organizations in the Philippines. Local institutions in Philippines have established early warning systems and disaster preparedness plans to protect fishermen and coastal communities from typhoons and extreme weather events (Iuchi et al., 2019). In Akplabanya, I found that governments work through NADMO to provide necessities for the community after flooding events, reflecting similar disaster relief efforts undertaken by government agencies in regions like the United States in the aftermath of hurricanes (Bullock et al., 2018). While government agencies like NADMO contribute to Akplabanya's resilience, there may be opportunities to learn from the proactive approaches implemented elsewhere and further enhance the adaptive capacity of the community to effectively respond to the growing challenges posed by climate change.

Coastal Indigenous Knowledge and learning has shaped adaptation response in Akplabanya, Ghana. The transformation of architecture from clay and thatch to block buildings due to recurring tidal surges reflects the adaptive resilience of Akplabanya's residents, similar to the experiences of Inuit communities in Canada's Arctic. These Inuit communities have adapted their housing designs to withstand harsh Arctic conditions, showcasing the dynamic nature of Indigenous adaptation (Ford et al., 2008; Park, 2018). However, maladaptive decision to build with beach sand due to salt intrusion in Akplabanya serves as a cautionary example, reminiscent of similar challenges faced by coastal Indigenous communities in the Pacific Islands, where sea-level rise has forced some to relocate and adapt their traditional building practices (Nunn, 2013; Vitousek et al., 2017). In the midst of coastal Indigenous knowledge change, learning play a crucial role in Akplabanya. In regions like Indonesia in Southeast Asia, fishers have adopted mobile technology to access weather information, share real-time data about fishing grounds showcasing the potential of technology-driven learning (Saville et al., 2015). However, it is essential to acknowledge that limited access to technology or digital literacy may hinder such knowledge-sharing endeavors. In some parts of Africa, including coastal regions, disparities in digital access and literacy pose challenges to utilizing mobile phones as effective learning tools (Pimmer et al., 2014).

2.5 Conclusions

Akplabanya in Ghana, like other coastal communities, faces ongoing perceived coastal social-ecological system changes. The key lesson from this research shows that this coastal community is changing in its fisheries system, land, freshwater system, livestock vegetation, and surroundings. The community, like other coastal communities, is responding to the ongoing change. The responses of Akplabanya to coastal social-ecological system change, exacerbated by climate change have 1) led the fishers to use technology to fish and share knowledge, 2) led fishmongers to depend on the market for items needed to process fish, and 3) led local and government institutions to aid fishers and fishmongers after extreme events like flooding from tidal surges. This new knowledge contribute valuable insights that can inform policy and interventions aimed at promoting adaptation and resilience in Akplabanya.

2.6 Limitation of study

This study in Akplabanya faced several limitations during fieldwork, like constraints on getting fishmongers for an over on hour interview, the possibility of sampling bias, language and cultural barriers, researcher bias, limited timeframes for data collection, unforeseen events with translator, and the potential for changing socio-economic and environmental contexts. These limitations could have affected the comprehensiveness, generalizability, and reliability of the study's findings. To address these challenges, I employed multiple mixed methods to triangulate data, and ethical and positionality considerations to work with Indigenous peoples, manage power in balances using a local research assistant and translator, maintain transparency, and acknowledge potential biases in this study. I verified data from various sources and engaging with the community collaboratively can enhance the validity of the research outcomes.

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Chapter 3: Conclusion

3.1 Introduction

The primary objectives of this research are O1) Identify the perceived social-ecological systems (SES) changes impacted by climate Change in Akplabanya, Ghana and, O2) Identify the key responses to these perceived social-ecological system changes. I employed four qualitative methods for two months in the field to address the objectives. I built on the combined lenses of resilience and social-ecological system in a conceptual framework from Ford et al. (2020) to address O1 and O2. In the context of Akplabanya's fisheries system, I focused on specific themes, such as freshwater use, land use change, climate change, biodiversity loss, and pollution, as drivers of environmental change, however, in adaptation to these themes, population change emerged as a theme. Additionally, I examined how the respondents adapt, cope, transform and build resilience, considering factors like place, collective actions, learning, agencies, local institutions, and Indigenous knowledge as influential codes in the analysis. In contrast to resilience, maladaptation emerged in responses from respondents.

In addressing O1, I found that Akplabanya's fisheries system in Akplabanya had changed from one social-ecological state to another. This can be seen in ways in which fishers and fishmongers experienced change in Akplabanya. Fishers experienced change in two ways: 1) The rise in sea levels, changing tidal patterns, and population increase have significantly impacted fishing activities, resulting in reduced fish catches and competition, and 2) Coastal erosion and flooding have led to substantial land loss and assets of fishers like outboard motors and fishing nets. Conversely, fishmongers have also experienced and influenced change in three ways: 1) Loss of vegetative cover, including coconut and neem trees, has affected food sources, and led fishmongers to a dependence on market centers for supplies, 2) Unsustainable refuse dumping practices by fishmongers and pollution in the community have contributed to health issues, including recurrent malaria, impacting the community's food sources and livelihoods, and 3) Fishmongers have lost their traditional smoking grass that gave the processed fish unique color and taste.

The themes that addressed O2 showed how Akplabanya coped, transformed, and adapt to social-ecological system changes in their fisheries system which resulted in some form of resilience and maladaptation. The ways in which Akplabanya coped, transformed, and adapt is shown in the livelihoods of fishers, fishmongers, and institutions in Akplabanya. Fishmongers responded effectively to coastal social-ecological system changes through two ways: resource replacement

and market adaptation. First, fishmongers coped with vegetation loss by replacing traditional smoking materials with items purchased from other communities. Second, fishmongers have also adapted to loss of farmlands by purchasing food from market centers. This adaptation highlights their flexibility in sourcing products and ensuring food security for households in the community. Meanwhile, fishers responded to low fish-catch in Akplabanya by transforming from fishing in the morning to fishing in the evening using technology like light fishing, as an adaptive response to declining fish catches. This innovation has transformed their fishing practices, leading to increased catches and economic stability, though population increase and big fishing trawlers have introduced competition. Fishers collaborate with local institutions, such as the Landing Beach Committee and Canoe Fishermen's Association, to provide support and incentives to those affected by tidal surges as a coping strategy to enhance their resilience as a community.

3.2 Policy Implications

Policy implications for Akplabanya encompass integrating Indigenous coastal communities into Ghana's national and regional adaptation strategies. This involves fostering multi-level governance and coordination to recognize climate change impact like coastal erosion and flooding as influencers of coastal social-ecological system changes like biodiversity loss in Akplabanya into policies like National Adaptation Strategy (2011) and the National Marine Fisheries Management Plan (2015-2019) (Evadzi et al., 2018). These policies should be tailored to the specific challenges faced by Akplabanya and communities like it, focusing on patterns in coastal fisheries, land use, and coastal resources (Egyir et al., 2015; Yankson et al., 2017). Additionally, efforts are needed to bridge knowledge and research gaps related to coastal social-ecological system in Indigenous coastal communities in Ghana, thereby facilitating evidence-based policy formulation and adaptation strategies (Codjoe & Dovie, 2019; Prosper & Khan, 2018). Government should adequately enforce resource allocation to ensure that policies are effectively translated into meaningful actions (Adu-Boateng, 2015; Ahenkan et al., 2021). The overall goal is to create a more inclusive, bottom-up and community-driven approach to climate adaptation, customizing strategies, and allocating resources effectively to foster resilience and sustainable development in Akplabanya (Samaddar et al., 2021).

3.3 General conclusion and recommendations

The study in Akplabanya has shed light on the complex and interconnected challenges faced by this Indigenous fishing community in the wake of social-ecological system changes. Through the

lens of social-ecological systems and resilience, I have gained valuable insights into the adaptive strategies, coping mechanisms, and resilience-building efforts of Akplabanya community. The study has highlighted that the social-ecological system changes in Akplabanya have led 1) the fishers to use technology with light to fish and with mobile phones to share knowledge, 2) fishmongers to depend on the market for items needed to process fish, 3) local and government institutions to aid fishers and fishmongers after extreme events like flooding from tidal surges. The implications of these findings can be extended beyond Akplabanya, offering valuable lessons for policymakers and researchers seeking to enhance adaptive capacity and foster sustainability in indigenous coastal communities worldwide (Arkhurst et al., 2022; Egyir et al., 2015). The implications of these findings also present several opportunities for future research. In future research, investigations can be focused on the effectiveness of specific adaptation strategies employed by the people of Akplabanya, with an emphasis on identifying best practices and areas for improvement (Arkhurst et al., 2022).

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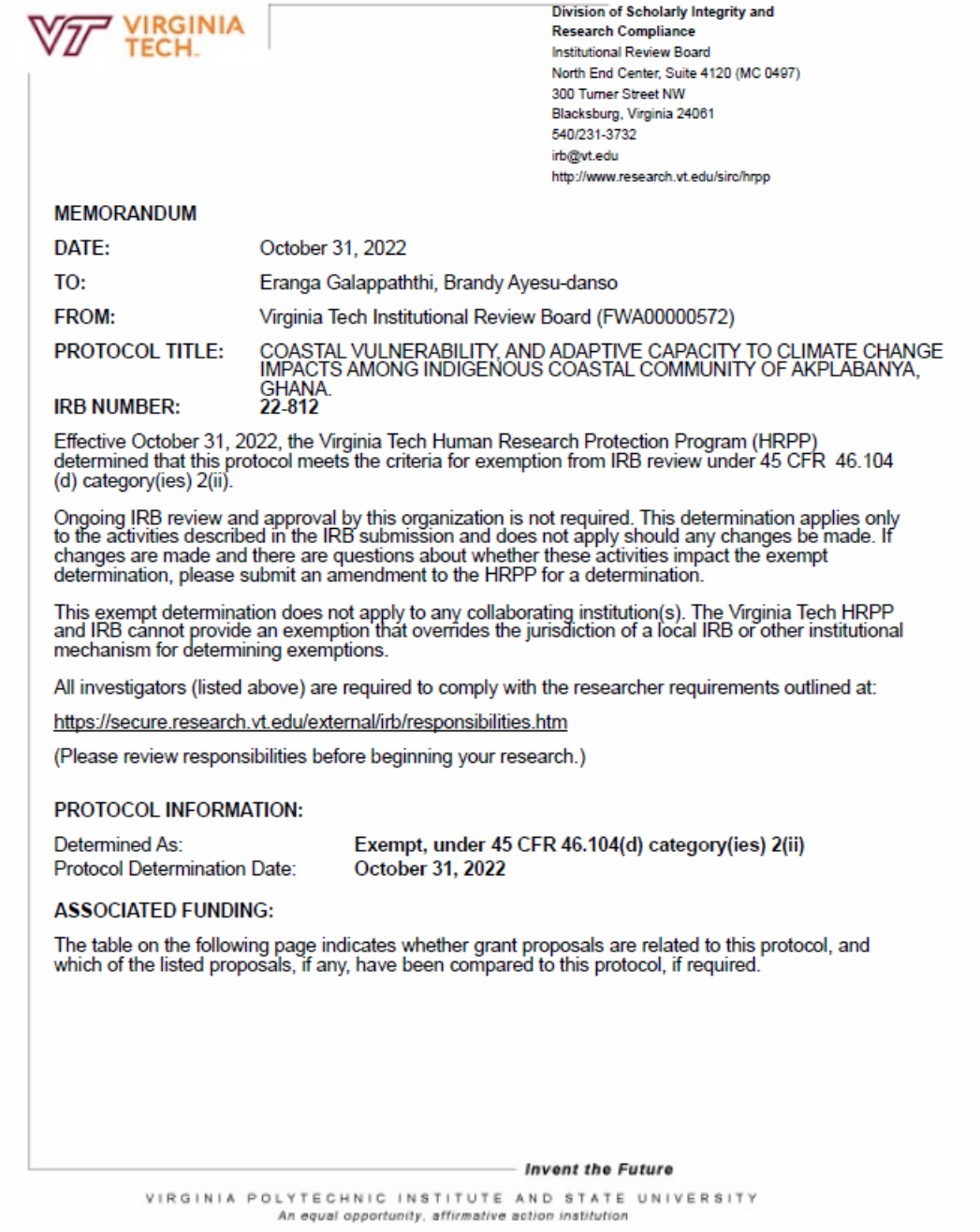
Appendix

Appendix A

IRB Approval Letter



VIRGINIA TECH

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MEMORANDUM

DATE: October 31, 2022

TO: Eranga Galappaththi, Brandy Ayesu-danso

FROM: Virginia Tech Institutional Review Board (FWA00000572)

PROTOCOL TITLE: COASTAL VULNERABILITY, AND ADAPTIVE CAPACITY TO CLIMATE CHANGE IMPACTS AMONG INDIGENOUS COASTAL COMMUNITY OF AKPLABANYA, GHANA.

IRB NUMBER: 22-812

Effective October 31, 2022, the Virginia Tech Human Research Protection Program (HRPP) determined that this protocol meets the criteria for exemption from IRB review under 45 CFR 46.104 (d) category(ies) 2(ii).

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit an amendment to the HRPP for a determination.

This exempt determination does not apply to any collaborating institution(s). The Virginia Tech HRPP and IRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Determined As: **Exempt, under 45 CFR 46.104(d) category(ies) 2(ii)**
Protocol Determination Date: **October 31, 2022**

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

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Appendix B

Supplemental material for Chapter 2

Table 3.1: The characteristics of SSI participants to support community profiles interviewed. (*n=61).*

Location of the study site and Demographic themes and questions	**SSI Participants response**	**Description of response**
Born in Akplabanya	Yes= 54(89%) No= 7(11%)	The higher percentage of participants were born in Akplabanya, while others were born in other areas within the Dangme tribe.
Community member	Yes= 61(100%) No= 0	Albeit all participants were community members because they had been living in Akplabanya for over 20 years
Number of years lived in Akplabanya?	18-25= 5(8%) 26-35= 12(20%) 36-45= 13(21%) 46-55= 10(16%) 56 and above= 21(35%)	Most participants had lived in Akplabanya for over 56 years, while few of them had lived in Akplabanya for less than 25 years
Ancestors hail from Akplabanya	Yes= 35(57%) No= 26(43%)	A higher percentage of participants also hailed from Akplabanya, while others immigrated to Akplabanya because of fishing activities and marriage.
Where participants live	South= 40(66%) West= 18(30%) East= 1(2%) Central= 1(2%) I don't know= 1(2%)	The entire settlement is densely populated in the south due to its proximity to the coast. Thus, a higher percentage lived in the south and the southwestern part of Akplabanya.
Subsections in Akplabanya	Able to recollect=56 (92%) Unable to collect= 5(8%)	Akplabanya has 16 subsections and most of the participants were able to recollect and mention them. On the other hand, few people were unable to recollect it.
households per subsection	Able to recollect=8(13%) Unable to collect= 53(87%)	Akplabanya has many families representing the various households present in the community. A higher percentage was unable to recollect while few did.
Number of people in the household (This includes those away)	1-50=33(54%) 51-100=9(15%) 101-150=4(7%) 151-200=5(8%) 201 and above= 10(16%)	Akplabanya owes its population to the number of people per household. A higher percentage of participants have less than 50 persons in their household while the rest had over 50 persons in their household
People in households who are working to contribute to generational wealth?	1-50= 54(89%) 51-100=2(3%) 101-150=1(2%) 151-200= 2(3%) 201 and above= 2(3%)	Most participants said persons who worked to support the household were less than or equal to 50, while few others mentioned the higher number of persons
Family units in household	1= 7(11%)	A higher percentage of participants had 10 or

	2-10=48(78%) 11-20=2(3%) 21-30=1(2%) 31 and above=2(3%) No idea= 2(3%)	less number of family units in the household, while a few others had 11 and above
Number of children	1= 2(3%) 2-5= 18(29%) 6-10= 29(47%) 11-20=4(7%) 21 and above= 4(7%) None = 4(7%)	Most participants had 10 or fewer children each while others had 11 children and above
Level of education 1. Never 2. Primary 3. Secondary 4. Tertiary 5. Graduate	Never= 25(41%) Primary= 22(36%) Secondary= 8(13%) Tertiary= 6 (10%) Graduate= 0	A higher percentage of participants had never attended school, those who did dropped out of primary school and a few others completed secondary and tertiary
Main job/jobs	Fisher= 33(54%) Fishmonger= 11(17%) Teacher= 2(3%) Canoe Wood seller= 1(2%) Business Trading= 3(5%) Fishing and another= 12(19%) None= 0	Most participants were fishers, followed by some fishmongers who combined other businesses with fish smoking during low fish catch. Other participants were fishmongers only, teachers, and others whose businesses depended on the fishing livelihood in Akplabanya
Do you work seasonally?	Yes= 16(24%) No= 45(74%)	A higher percentage of participants said they worked throughout the year, while others worked based on the fishing seasons of Akplabanya
What are jobs that last all year?	Fishing-related jobs that do not last all year= 25(41%) Fishing= 22(36%) Business Trading= 3(5%) Fish smoking = 7(11%) Wooding Selling= 1(2%) Teaching= 3(5%)	Though the majority of participants had seasonal jobs, the majority said they worked throughout the year
Range of monthly income in GH₵?	50-500= 13(21%) 501-1000= 11(18%) 1001-1500= 1(2%) 1501-2000= 4(7%) 2000 and above= 7(11%) No fixed amount= 25(41%)	Most participants could not tell what they earned within a month, nor could give an average range, while others said they earned less than GH₵500.
Do you have migrant family members and receive remittances from them?	No= 9(15%) Yes but no remittances= 24(39%) Yes, and remittances= 28(46%)	A higher number of participants said they receive financial support from families outside the community, other participants have family but receive no support. The rest had no family outside Akplabanya
Have your family members or you ever lived outside of the community? Why did they leave?	No= 4(7%) Yes, other reasons= 51(83%) Yes, Climate related reasons= 6(10%)	While families of the responders had moved out of Akplabanya due to various reasons, few had relocated due to recurring floods. Others had families in Akplabanya.

Did you move from a different place to Akplabanya? why?	No= 12(19%) Yes, other reasons= 23(38%) Yes, Climate related reasons= 26(43%)	A higher percentage of participants moved from and returned to Akplabanya before 2015 due to low fish catch and economic hardship

Appendix C

Data collection instruments

Brandy Ayesu-Danso #22-812

Eranga Kokila Galappaththi (PI)

1) Identify the social-ecological system changes in Akplabanya, Ada West, Ghana

2) Identify the key adaptation responses to the social-ecological system changes in Akplabanya, Ada West, Ghana.

Semi-structured interview guide

Location of study site and Demography (place and people: maps, photos, and videos)

Were you born here? Are you a community member?

How long have you lived in Akplabanya?

Did your ancestors hail from Akplabanya?

In which part of Akplabanya do you live now?

Can you show me or what is it called?

How many subsections are there in Akplabanya?

And how many households per subsection?

How many people live in your household? (This include those away)

How many females in the household? How many males?

How many of them are working to contribute to generational wealth?

How many family units are there in your household?

How many children do you have? Number of Female children? Number of Male children?

What level of education do you have? 1. Never 2. Primary 3. Secondary 4. Tertiary 5. Graduate

What is your main (are your main jobs?) Do you work seasonally, what jobs are there in the different seasons?

What jobs are there that last all year?

What is your range of monthly income in GH₵?

Do you have migrant family members? Do you receive remittances from them?

Have your family members or you ever lived outside of the community? When and how long?

Did you move from a different place to Akplabanya? If so, how long ago was it? And why?

Objective 1 - To understand the SLR-related vulnerabilities of Indigenous community of Akplabanya

Q1 How have you experienced climate change?

1. History and timeline of people and place (table/figure: event name, description, year, etc.)

- First flood ever experienced and last flood from Tidal waves and rainfall

- The practiced cultural changes you witnessed in Akplabanya?

- Explain/sketch/point out what is here today and what is not

2. If ever questioned about hometown and what has changed over some years ago

3. Proof of climate change and its impacts in the lives of the participants

4. Role of coastal erosion, rain, and tides; climate change believer, changes, effects, and impacts of climate, which social group is affected the most

Q2 How have you experienced social ecological systems change?

5. Links between the people and their environment

- What does the sea and the fish in it mean to you?

- What does the river Akplaba mean to you?

- What does the livestock in Akplabanya mean to you?

- What does the land of Akplabanya mean to you?

- What does the vegetation in Akplabanya mean to you?

6. Mapping Social-ecological systems change. What are all the changes in the linkages mentioned above?

7. List resources and how resources have changed over the years? Water, land, sea, vegetation? Education, internal and external support, Traditions?

8. How the way of life of the people have changed over the years; list of food, clothing, hair, accessories/adornments – Can you show me photos

9. What are the primary drivers of these changes?

10. What are the secondary drivers of these changes?

Q3 What are the community perceptions about climate change impacts?

11. About sea-level rise and perceptions towards it (Buried buildings prove it?), direction of change

12. Perception of flooding/Tidal waves/storm surges, direction of change over the years

- occurrences per year, lost things during flooding/Tidal waves/storm surges

13. Perception of rainfall, direction of change over the years

- occurrences per year, lost things during rain

14. Perception of the rate of sand deposition on the beach of Akplabanya, and its direction of change

15. Perceptions about future changes in sea levels

16. Perception about future flooding/Tidal waves/storm surges, direction of change

Objective 2 - To examine the adaptive capacity of Indigenous people to the ongoing social-ecological systems change due to sea-level rise.

Q1 What are the adaptive responses that minimize vulnerability and build resilience in social-ecological system context (Human responses)

1. Akplabanya's adaptation strategies to tidal waves, rainfall, and coastal erosion problem so far

2. government's actions for the community so far

- What do they do when they come, how long do they stay when they come, how often do they visit, how long do they take to visit?

3. Presence of NGOs and private organizations

4. National departments like the ministry of fisheries and National disaster management organization (NADMO)

Q2 What are the existing adaptive capacities?

5. Current adaptive capacity. Community level? Individual level? Or Regional level?

6. Which areas of Akplabanya has high adaptive capacity than other areas

7. Indigenous knowledge in the role of adaptive capacity. Education, internal and external support, Traditions?

8. current ecological damage control on living organisms due to climate change. Water, land, sea, vegetation? Example.

- What are the measures implemented to make the fishing experience just like the good old days?

- What are the measures implemented to make the Akplaba river like how it used to be years ago?

- What are the measures implemented to protect and preserve livestock deaths??

- What are the measures implemented to make the Akplabanya land like how it used to be years ago??

- What are the measures implemented to make vegetation in Akplabanya like how it used to be years ago??

9. Adaptive capacity of Coral reef of the beach

10. What does the Government say you should not do to address climate change in their district and Akplabanya.

11. Which policy has government implement so far in Akplabanya

12. The Media's role in adaptative capacity

Q3 What are the existing adaptive capacity that need interventions?

13. Which climate change intervention currently serve its purpose, and which one does not?

14. Why did you choose the ones that serve their purpose

15. Why did you choose the ones that do not serve their purpose

16. What changes do you want to see in climate change interventions?

17. Recommendations/solutions in mind to reduce social-environmental impact in Water, land, sea, vegetation?

Key informant interview guide

History of community

Event name	Description	Time (start and end)

1. How many years ago was Akplabanya discovered and what is the history surrounding the community?

2. How many years ago did the first Christian missionaries arrive in Akplabanya?

3. How many years ago did education come to Akplabanya?

4. Can you tell me about the first canoe ever made in Akplabanya?

5. Can you tell me about the first whale to ever be washed onto the shores of Akplabanya?

6. what was the first god to be worshipped here in Akplabanya and how many years ago was that?

7. Can you please tell me the history of the first vehicle to be brought/bought to/in Akplabanya?

8. Can you tell me the history about the first Indigenous healing in Akplabanya?

9. Can you tell me the history of the first clinic in Akplabanya?

10. When was the first livestock disease break out in Akplabanya?

11. How many years ago did Premise fuel arrive and what is the history about it?

12. How many years ago did the first outboard motor arrive in Akplabanya and what is the history surrounding it?

13. How many years ago did commercial fishing begin in Akplabanya and what is the history surrounding it?

14. When was the first convenient store in Akplabanya?

15. When was the first alcoholic bar in Akplabanya?

16. When did electricity arrive in Akplabanya?

17. What was the first every biggest disease outbreak and the history around it?

18.Who was the last clan to arrive in Akplabanya and how many years ago was that?

19. After the establishment of electricity, when was the first blackout in Akplabanya?

20. Was COVID_19 ever recorded in Akplabanya?

21. How many years ago did Akplabanya begin to practice Light Fishing and what is the history surrounding it?

22. Whish year did the Government try to stop light fishing and what is the history surrounding that?

23. When was the first Mill machine in Akplabanya, who brought it, and how many years ago was that?

24. Can you please tell me UNICEF's work in Akplabanya?

25. Any other memorable events you would like to share?

Focus Group Discussion (FGD) guide

FGD - 1

FGD: Number of participants=5 (3 males, 2 females)

Made up of Fishers and Fishmongers

Observed Changes (From SSI compilation	Level of agreement1 (Observation in FGD)	Causes/Drivers of Observed changes	Directions: change direction:	Impacts of observed changes	Potential future Scenarios
	Select: fgd agreement: Disagreed, Disagreed after debate, agreed after debate, fully agreed	Text/Describe	select multiple: change direction: appearance, increase, more, higher, longer, later, stronger, faster, decrease, less, lower, shorter, sooner, weaker, slower, disappearance, other (text)	(Fishers, Fishmongers, Children, The elderly)	Text/Describe
4 - "In terms of rainfall and sunshine, I know some seasons have more rainfall and others have more sunshine, and I have experienced changes where seasons with fewer rainfall now has more and seasons with less sunshine is now warmer"					
5 - "Fruit trees like coconut trees no longer exists, grass as playground no longer exists, and it all started after the tidal waves continue to come and come and come"					
6 - "Tidal waves and storm surges have intensified over time. Previously, it used to come twice a year on the 9th of August and					

11th September around the years 2000, 2005, 2009, 2011. But now, we can no longer predict when the tidal waves will just come into the town. It has already occurred 4 times in April, July, August, and September"					
8 - "Previously, the soil of Akplabanya was not salty at all so they cultivated food crops like vegetables and cassava, but as the sea level drew closer to the community, the soil has been infiltrated by salt, so we lost the natural food resource from the land"					
9 - "40 to 45 years ago, when anyone was sent to go deliver food to fishers at the shore, they would be upset because it was so far, and would like to be accompanied but now, the sea is so close such that it's in the town"					
11 - "There used to be a river called Sangleteh (A river that used to exist) between the community and the sea. The Sangleteh river prevented Akplabanya from flooding but now, the sea has swallowed Sangleteh and it is no more"					
15 – "The livestock we keep used to have ready grass for them to feed on and grow healthily, but now, due to the saltwater intrusion, grass no longer grows for them to feed on, so they can't grow properly"					

16 – "We used to use to drink Akplaba, cook with it and use it for other domestic purposes, but now we can no longer do that" (All benefits)					
18 – "When it's raining or when we have rains, when the rains are coming, the sea becomes calm and very very cool and so during that time we have a lot of fish but because today the rains are not coming, we are not having the rainfalls, we are not able to catch fish from the sea"					
23 – "There's a particular fish species called kakatoa, those days, this kakatoa fish was so so so sweet, very delicious, and that when it is smoked for you or roasted for you and you enjoy, you will feel like staying here and not going again. But today, that kakatoa fish species is not there again. And then this big type of tuna, the heavy type of tuna, when the fishers used to go, they get them, but now they are no longer there. About 15 (2007) years ago, we have not seen these fishes again"					
38. "We no longer get certain species of fishes ever since these trollers that have come, that are used in fishing, they are killing all these fishes in the sea so when we go, we do not find them. We are certain that they are killing those fishes. The fishing nets they use					

are very wider and bigger than the ones we use and so when they cast their net, they cover very large portions of the sea. And so sometimes they kill plenty of the fishes where some became dead and rotten in the sea, and so the living fishes, when they get the scent of the fishes like that, they have to run away, they have to escape"					
41. "Because the sea keeps pushing us forward and forward, we are forced to dump refuse into the Akplaba river so we can make space (for building) to continue with our fish smoking business. Even here we are seated, those days, the Akplaba river was here"					
46. "In terms of other cultural practices of spiritual and ancestral powers, we have our own ordinances to take control of the land but because of Christianity, all these practices are no longer done"					

FGD - 2

FGD: Number of participants=5 (3 males, 2 females)

Made up of Fishers and Fishmongers

Observed Responses to Changes (From SSI compilation, Key Informants and Observation)	Level of agreement1 (Observation in FGD)	Adaptation/ coping agent (who does the measure)	Decisions	Institutions involves	Maladaptation | Sustainability angle
	Select: fgd agreement: Disagreed, Disagreed after debate, agreed after debate, fully agreed	Text/Describe	How are decisions made. Text/Describe	Institution Structure and roles in the community. Text/Describe	Text/Describe the
1. "The chief sometimes gets machines and equipment to constructs temporary trenches to let the water flow out of the town" - "The chief is in charge of the common space and common land" **- Local leadership institution**					
4. "When our canoes and fishing materials get destroyed by tidal waves, there are some contributions to get the materials for the household with the most damage" **– Landing Beach Committee**					
6. "The Chief fisherman has said no one should win sand at the beach so we do not do it" "Ministry of Fisheries send their delegates to come and inform the					

Chief of the fishers that they should say off seas for the months of June and July as a means to enhance fish reproduction” ““Few of the fishers got the opportunities to learn a little bit about the usage of GPS and Compass technology from big trolleys and taught us the little they know. So, we learned how to use the equipment ourselves” **- Fishermen Association**					
12. “Because the sea keeps pushing us forward and forward, we are forced to dump refuse into the Akplaba river so we can make space (for building) to continue with our fish smoking business” - “We have fish mongers association that sometimes meet to share ideas” **- Fishmongers Association**					
13. The women and children because some of us have houses around Sege, Kasse, and some other surroundings where the waves cannot get to, they leave to go to our houses there and when the waves are gone then they come back again.					

- "During that time, we leave to our friends and relatives close by to perch until the water flows back to the sea" - "We depend on livestock for food and money when fish catch reduces or there is no fish catch" **- Individuals**					
15. "During that time, we leave to our friends and relatives close by to perch until the water flows back to the sea" - "When it floods, we take our holes, shovels, and other tools to create channels for the water to flow out of the community" **- Community**					
16. "Government sometimes send representatives during tidal wave intrusion into the community to come and assess the problem" **- Government**					
18. "Ever since light fishing came to Akplabanya, there have been more development; building, Higher education, Good standard of living" **- Light Fishing**					
23. "NADMO last came in April this year with few clothing and beds. Sometimes when Akplabanya is					

flooded, NADMO officials come in with their rubber safety boots to assess the extent of Damage and leave" **- NADMO**					
25. "Today as we are seated and discussing, traditions are performed and when the tidal waves come, they find themselves back into the sea. Some came around 2018, those libations were poured and then traditions were performed and then it went back" **- Indigenous Knowledge**					

FGD - 3

FGD: Number of participants=5 (3 males, 2 females)

Summary of Observed responses (From SSI and PO compilation)	Level of agreement (Observation in FGD)	The climate change impacts addressed by the Adaptation	Drivers for Adaptation measure	Adaptation/ coping agent (who does the measure) and Institutions involves	Limitations of Adaptation	Maladaptation
	Disagreed, disagreed after debate, agreed after debate, fully agreed	List	What drives you to do this adaptation response Text/Describe	Institutions and the criteria they use in putting in these measures. Text/Describe	Setbacks of the adaptation response (E.g., Light fishing is expensive)	Things wrong with the measures put in place Text/Describe (Even with light fishing fish cate is still low)
1. Our men create water channels for floods from tidal waves to flow out of the community into the sea.						

2. Our men create water channels for floods from rainfall to flow out of the community into the sea.						
3. We have been asked to stop sand winning to reduce the impact of tidal waves on the community						
4. The chief organizes for bigger machines to dredge some parts of the Akplaba for floods from tidal waves to flow back to the sea and to the next village						
5. We dump refuse in the Akplaba to create space for building of houses, fish smoking sheds and ovens (Malaria)						
6. We have employed the technology of light fishing though (its expensive to use it)						
7. We got pipe and use pure water for domestic use and drinking as we can no longer fetch water from the Akplaba and other rivers						
8. Light fishing came to solve the low fish catch issue we faced after the Witsii god's shrine was washed away by the tidal waves						
9. Japanese/Koreans aided in bringing electricity to Akplabanya to help identify the coast when coming to buy fish from us						
10. Compassion NGO group advise and motivates children to attend school by meeting and supplying them with school materials like Stationaries, food, sometimes beds						

11. Contributions are made for the affected when fishers' fishing gears are destroyed						
12. The not-so affected persons help keep sensitive belongings of the affected persons when tidal waves hit us						
13. We have fishing holidays on Tuesdays and Sundays						
14. During Tidal waves, the fishers anchor their canoes far from far from the shoreline						
15. NADMO comes with relief items like mattresses, used clothes, bags of grains and blankets to be distributed among the affected persons during tidal waves						
16. The people of Akplabanya embraced Christianity after all the priests and priestess died						
17. We depend on our livestock for food and money when fish catch is low						
18. Some fish mongers buy frozen fishes from Tema to come and smoke during low/no fish catch and annual two-month fishing holiday (June & July)						
19. We observe the ministry of fisheries' annual two-month fishing holiday (June & July) for fish rejuvenation						
20. We buy food stuffs from outside Akplabanya as we no longer cultivate crops (Tubers, vegetables, and fruits)						