Norwegian University of Life Sciences
Department of International Environment
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Philosophiae Doctor (PhD)
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Small scale fishing communities' perceptions of climate change and its impact on livelihoods, gender roles and adaptive capacity – A case of Lake Malawi.

Småskala fiskesamfunns oppfatninger om klimaendringer og innvirkning på levekår, kjønnsroller og adaptiv kapasitet – et kasus fra Lake Malawi

Moses Majid Limuwa

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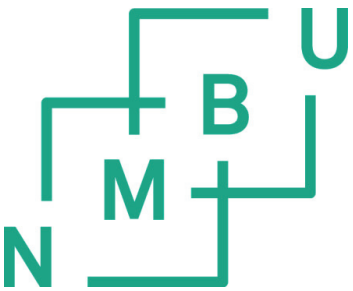

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Dedication

This thesis is dedicated to my late father (*Parineti Wayiya Rimuwa – 13.10.1934 – 31.07.2018*). Closing your eyes while I was thousands of miles away from home, will always remind me of how you inspired me to work hard.

Summary

Fisheries remain a major livelihood for many Malawians despite continued low fish catches negatively impacting households, which depend on this resource. The main objective of this thesis is to reduce the current lack of empirical evidence on added impacts of climate related changes and how fishing communities are coping with such changes. Malawi has been experiencing extreme weather events that affect livelihoods. Therefore, in addressing this major objective, four interlinked research studies were conducted in Nkhotakota, a lakeshore district on the western shores of Lake Malawi, which has been experiencing such extreme weather events. These four studies examined aspects of perceptions to changes in fish catches and climate; gendered fish value chain; alternative livelihood sources; and enhancing adaptive capacity through development initiatives.

To respond to these aims, the interlinked studies were guided by different theories and conceptual frameworks. The main conceptual framework for this thesis is the sustainable livelihood framework. Other additional concepts and theories including gender and development, vulnerability, and sustainable food systems were also used. The research was conducted in phases between August 2015 and August 2017. The research used mixed methods (qualitative and quantitative) in data collection and analysis. This thesis is framed around 671 household interviews, 40 focus group discussions and 25 key informant interviews. Content analysis for related themes was the major qualitative method, while quantitative methods involved both descriptive and inferential statistics. The main findings from the four interlinked studies are presented in the following sections.

In the first paper, perceptions of small scale fishers and their coping strategies for extreme weather events were evaluated. The results revealed increased incidences of extreme weather events. However, the analysis of climate variables such as temperature and precipitation did not reveal significant changes. This study cautions against relying on perceptions despite local knowledge is useful in the absence of conventional scientific knowledge. The study also showed multiple livelihoods diversification strategies in response to perceived low fish catches. However, some of these coping strategies were not sustainable for the fishery.

In the second study, gender analysis was used to evaluate whether perceived changes in climate impacts the fish value chain and livelihoods. The results showed that coping strategies for perceived changes was gendered. Furthermore, more women were involved in post harvesting

fisheries activities compared to men, who were catching the fish. The study also revealed an influx of women in fisheries was attributed to high purchasing power of fishing equipment and not on perceived changes in climate. However, women were employing men to catch fish on their behalf. Despite the increased participation of women, they still lacked power to control the proceeds from fisheries related incomes. Furthermore, this study showed changes in livelihood portfolios from agriculture to fisheries.

The third study we evaluated the importance of fish farming as a sustainable livelihood coping strategy. The study showed that the respondents did not consider fish farming as their major livelihood source attributed to small fish earthen ponds. Fish farming was also androcentric despite women being custodians of the farming land. Even though land and water were available to expand fish farming, farmers cited lack of quality inputs and extension services as major challenges. Furthermore, there were conflicts related to water usage with rice farmers and recycling of residues from farm animals and plants to fertilize fishponds, as farmers opted to use the same in agricultural fields.

Finally, in the fourth study, we assessed development initiatives, livelihood assets and adaptive capacity among the fishing communities. Participants for the groups of development initiatives were characterised by low incomes from fisheries and remittances; small land holding sizes and had lived in the study area more than non-participants. Even though the study showed the impact of some initiatives in enhancing adaptive capacity, some selection bias existed. The study also revealed high-income inequalities for both beneficiaries and non-beneficiaries. The paper also showed the potential for development initiatives especially infrastructure in reducing vulnerability and income inequalities even though their focus were not climate change oriented.

The findings from this thesis provide a basis for forming and implementing evidence-based policies in countries whose people rely on climate-sensitive livelihoods. For instance, these findings can be used to inform the Malawi National Fisheries and Aquaculture Policy as well as the participatory fisheries management framework that lacks strategies to deal with climate-related changes and other important socioeconomic factors such as gender. Additionally, other service providers in rural areas can frame their strategies based on the findings of this thesis.

Sammendrag

Fiske er fortsatt en viktig levevei i Malawi, til tross for at dårlige fangster har en negativ påvirkning på husholdningene, som er avhengige av denne ressursen. Hovedmålet for denne avhandlingen er å redusere dagens mangel på empiriske bevis for virkningene som følger av klimarelaterte endringer, og hvordan fiskerisamfunnene takler disse endringene. Malawi har opplevd ekstremværhendelser som påvirker levekårene. Under arbeidet med dette hovedmålet ble det derfor utført fire innbyrdes relaterte forskningsstudier i Nkhotakota, et distrikt på den vestlige bredden av Malawisjøen, som har opplevd slike ekstremværhendelser. Disse fire studiene undersøkte aspekter ved oppfatningene av endringer i fiskefangst og klima; verdikjeden for fisk med hensyn til kjønn; alternative kilder til levebrød; og å styrke kapasiteten for tilpasning til klimaendringer gjennom utviklingstiltak.

For å ivareta disse målene, ble de innbyrdes relaterte studiene styrt av ulike teorier og konseptuelle rammeverk. Det viktigste konseptuelle rammeverket for denne avhandlingen er rammeverket for bærekraftige levekår. Det ble også brukt andre tilleggskonsepter og teorier, herunder kjønn og utvikling, sårbarhet og bærekraftige matsystemer. Forskningen ble utført i faser mellom august 2015 og august 2017. Forskningen brukte blandede metoder (kvalitative og kvantitative) til datainnsamling og analyse. Avhandlingen bygger på 671 husholdningsintervjuer, 40 fokusgruppediskusjoner og 25 intervjuer av viktige informanter. Innholdsanalyse for relaterte temaer var den viktigste kvalitative metoden, mens kvantitative metoder omfattet både beskrivende og inferensiell statistikk. De viktigste resultatene fra de fire innbyrdes forbundne studiene presenteres i følgende avsnitt.

Den første undersøkelsen evaluerte oppfatningene til småskalafiskere, og mestringsstrategiene de brukte ved ekstremværhendelser. Resultatene avdekket økt forekomst av ekstremværhendelser. Analysen av klimavariabler som temperatur og nedbør, avslørte imidlertid ikke signifikante endringer. Denne studien advarer mot å stole på oppfatninger til tross for at lokalkunnskap er nyttig i fravær av konvensjonell vitenskapelig kunnskap. Studien viste også diversifiseringsstrategier med flere leveveier som en reaksjon på det som ble oppfattet som dårlig fiskefangst. Noen av disse mestringsstrategiene var imidlertid ikke bærekraftige for fiskeriet.

I den andre studien ble kjønnsanalyse brukt til å evaluere om oppfattede endringer i klimaet påvirker verdikjeden for fisk og livsgrunnlaget. Resultatene viste at mestringsstrategiene for oppfattede endringer var kjønnet. Flere kvinner var involvert i aktiviteter etter selve fisket

sammenlignet med menn, som var de som fisket. Studien avdekket også at tilgangen av kvinner i fiskeriene ble tilskrevet høy kjøpekraft for fiskeutstyr, og ikke oppfattede klimaendringer. Imidlertid ansatte kvinner menn til å fiske for seg. Til tross for den økte deltakelsen fra kvinner, manglet de fortsatt myndighet til å kontrollere fortjenesten fra fiskerirelaterte inntekter. Dessuten viste denne studien endringer i levebrødsporteføljer fra landbruk til fiske. Den tredje studien evaluerte betydningen fiskeoppdrett har som en bærekraftig mestringsstrategi når det gjelder levekår. Studien viste at respondentene ikke vurderte fiskeoppdrett som det viktigste levebrødet på grunn av at jorddammene er så små. Fiskeoppdrett ble også ledet av menn, til tross for at det var kvinnene som styrte jordbrukslandet. Selv om de var tilgang på både land og vann slik at fiskeoppdrettet kunne utvides, oppga bøndene mangel på kvalitetsfôr og landbrukstjenester som store utfordringer. Dessuten var det konflikter med risbøndene knyttet til vannbruk og resirkulering av rester fra husdyr og planter for å gjødsle fiskedammene, ettersom bøndene bruker det samme på åkrene.

I den fjerde og siste studien vurderte vi utviklingstiltak, levekårsressurser og adaptiv kapasitet blant fiskerisamfunnene. Deltakerne i gruppene med utviklingstiltak var preget av lave inntekter fra fiskeri og overføringer, de hadde små landstykker og bodd i studieområdet lenger enn de som ikke var deltakere. Selv om studien viste at noen tiltak for å forbedre den adaptive kapasiteten hadde virkning, eksisterte det noe utvalgsbias. Studien avdekket også ulikheter med hensyn til høye inntekter for både mottakere og dem som ikke er mottakere. Studien viste også potensialet for utviklingstiltak særlig rettet mot infrastruktur for å redusere sårbarheten og inntektsulikheter, selv om fokuset for disse tiltakene ikke var orientert mot klimaendringer.

Funnene fra denne avhandlingen gir grunnlag for å danne og implementere kunnskapsbasert politikk i land der innbyggerne er avhengige av levebrød påvirket av klima. For eksempel kan disse funnene brukes som informasjon til den nasjonale fiskeri- og akvakulturpolitikken i Malawi, samt styringsrammeverket for deltakende fiskerier som mangler strategier for å håndtere klimarelaterte endringer og andre viktige sosioøkonomiske faktorer som kjønn. I tillegg kan andre tjenesteleverandører i rurale områder bygge strategier basert på funnene i denne avhandlingen.

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List of acronyms and abbreviations

ADF	African Development Fund
AIDS	Acquired Immune Deficiency Syndrome
BVCs	Beach Village Committees
CABMACC	Capacity Building for Managing Climate Change Programme in Malawi
DoF	Department of Fisheries
EAFA	Ecosystems' Approach to Fisheries and Aquaculture
ENSO	El Niño–Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FDGs	Focus Group Discussions
GAD	Gender and Development
GCMs	Global Circulation Models
GDP	Gross Domestic Product
GoM	Government of Malawi
GPS	Geographical Positioning System
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HIV	Human immunodeficiency virus
IPCC	Inter-governmental Panel on Climate Change
KIIs	Key Informant Interviews
LDF	Local Development Fund
LFMA	Local Fisheries Management Area
MFA	Norwegian Ministry of Foreign Affairs
MGDS	Malawi Growth and Development Strategy
MK	Mann-Kendall
MKW	Malawi Kwacha
NFAP	National Fisheries and Aquaculture Policy
NGO	Non-Governmental Organization
NSO	National Statistics Office
PhD	Philosophiae Doctor
SADC	Southern Africa Development Community
SFS	Sustainable Food System
SLF	Sustainable Livelihood Framework
TA	Traditional Authority
UNDP	United Nations Development Programme

UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Aid for International Development
US$	United States Dollar
VSLs	Village Savings Loans

PART ONE: Synthesis Chapter

1. INTRODUCTION

1.1 Background

There is low awareness of sustainable management of global inland fisheries, despite their importance in providing livelihoods for billions of people (FAO 2014; Beard *et al.* 2016). Globally, the majority of people involved in small scale fisheries and related activities are from developing countries (Allison & Ellis 2001). With massive numbers of people's livelihoods relying on fisheries, the importance of sustaining small scale fisheries should be recognized (Pauly 1997; Allison 2001). It is therefore important that fishing grounds maintain their productivity in the presence of major disturbances, caused by intense stresses and large changes (Conway 1985).

One such type of stress is the impact of climate on the economies, distribution, and production of individual fisheries (Lehodey *et al.* 2006; Brander 2007; Allison *et al.* 2009; Cheung *et al.* 2009; Brander 2010; MacNeil *et al.* 2010; De Young *et al.* 2011; Mahere *et al.* 2014). For example, the inter-annual and decadal climate variability manifests itself through fluctuations of fish catches (King 2005). Climate change is an external driver of fisheries (Mills *et al.* 2011), that threatens biodiversity and ecosystems. Graham and Harrod (2009) reported that "changes in climate and in particular, temperature have and will continue to affect fish at all levels of biological organization". The numerous interactions within fishery ecosystems, including climate related factors, present complex scenarios in planning for fisheries management. These complexities highlight the need for climate change adaptation to be increasingly recognized as an imperative development policy for the twenty-first century (Adam 2015), and a catalyst for strategies that are likely to be available in many countries' development agendas (Stage 2010). Yet, many countries that depend on fisheries have low capacity to adapt to the impacts of climate change and are at risk of serious socio-economic collapse (FAO 2011).

The capacity to also manage fisheries and other natural resources under a changing climate depends on accurate future predictions of ecological conditions and the ability to manage ecosystems in a way that buffers against some of the predicted changes (Gama *et al.* 2014; GoM 2016; Paukert *et al.* 2016). The need for accurate information is important in socio-ecological systems (Folke *et al.* 2010).

Most rural households' adaptation ability are also affected by limited financial resources and knowledge (FAO 2011). This results in inconsistent responses when managing responses to changes due to weak links between the social, economic, and biological dimensions of fish

conservation practices (Arlinghaus *et al.* 2002). For example, in the face of declining resources, small scale fishers tend to intensify use of unsustainable methods which do not comply with fisheries regulations (Allison *et al.* 2007). This practice is common in other natural resources that form livelihood bases such as forests, where illegal activities are conducted due to climatic changes (Mosberg & Eriksen 2015). However, lack of understanding by policy makers on human drivers and associated resources affecting willingness to adopt alternative livelihoods in different local contexts is limited due to a lack of up to date information (Slater *et al.* 2013). Similarly, there is the need to understand fishers' attitudes towards exiting the fishery and how different socioeconomic factors affect such processes (Muallil *et al.* 2011).

Therefore, sustainable fisheries exploitation relies on understanding the interface between the fishers and their ecosystem (Pitcher & Hart 1982; Nsiku 1999; Kachilonda 2014). To date, global and regional climate vulnerability assessments have focused more on agricultural production, whereas fisheries are only partially evaluated (Schmidhuber & Tubiello 2007; Brugère 2015; Brugère & De Young 2015). Furthermore, most research on climate change vulnerability is centered on analyses of climate rather than societies and political economies (Eriksen *et al.* 2015). Thus assessing the small scale fishers' vulnerability to climate change enables formulation of clear and effective responses (Barsley *et al.* 2013). As with any other natural resources, the availability of accurate and relevant information on fisheries resources is an essential prerequisite for sustainable fisheries management (GoM 2016).

Based on the aforementioned background, this thesis maps livelihood possibilities in the context of changes to fisheries in general, including possible ecosystem changes, climate variation, promotion of fish farming, and development support. In addition, the thesis also unveils how gender influence social economic welfare under the influence of fluctuating fish catches, and also how development initiatives impact adaptive capacity of vulnerable fishing communities.

1.2 Context of the research

To fill the knowledge gaps on the interface between small scale fishers and climate change, it is important to contextualize the available knowledge. Geographically, the area of focus is Malawi, a landlocked country situated in the south of Africa. Malawi shares borders with Tanzania, Mozambique, and Zambia. Its population during the 2008 census was 13.06 million people with a growth rate of 2.8% per year (GoM 2008). However, in 2017 the population was estimated at 17.2 million with an annual growth rate of 3.1% (UNDP 2016). Malawi is divided into three administrative regions (north, central and south). Of the three regions, the north is less populated

compared to the other two regions (GoM 2008; GoM 2016). The poverty headcount (percent below poverty line) for Malawi is 50.7%, while the Gini coefficient for consumption was 0.45 (NSO 2012). Malawi follows an agriculture-based development agenda (Droppelmann *et al.* 2012) and its agriculture policies reflect neopatrimonialism (Phiri & Edriss 2013). The majority (90%) of the population live in rural areas and are constrained to smallholder farming. Furthermore, Malawi's economy is dominated by maize production (mainly for domestic consumption) and tobacco (mainly for export). Despite current reports of improved agricultural production due to input subsidies to smallholder farmers (GoM 2018), Malawi has been continuously experiencing food shortages at the household level attributed to small land holding size, food prices, limited use of modern inputs, poor access to markets, lack of farm inputs, and natural disasters such as erratic rains, water logging, drought, floods, and crop pests (NSO 2012; GoM 2017). These challenges make Malawi's agricultural sector receive greater development attention compared to other sectors. This focus on agriculture might have also led to neglecting development of other equally important sectors such as fisheries.

Inland fisheries offer alternative livelihoods in times of low agricultural output in many land-locked sub Saharan African countries similar to Malawi (Allison *et al.* 2002; Béné 2003; Béné *et al.* 2003; Allison & Horemans 2006; Ngoma 2010; Hatlebakk 2012). Malawi fisheries are important to both its economy and overall food security. Malawi's fishing industry supports nearly 1.6 million people in lakeshore communities and makes substantial contributions to their livelihoods. For example, in 2017, the sector had 62,028 fishing gear owners and crew members representing a 3% increase from 2016 (GoM 2018).

Fish has been the main source of animal protein in Malawi, consisting of over 70 % of the dietary animal protein intake and 40 % of the total protein supply. A significant share of fish is consumed in rural areas thereby contributing significantly to the daily nutritional requirements to some vulnerable groups such as HIV and AIDS victims, orphans, and marginalized people (Mumba & Jose 2005; GoM 2014). Despite the importance of fish in the nutrition of many Malawians, fish make up less than 2% of Malawi's Gross Domestic Product (GDP) (De Graaf & Garibaldi 2015). However, in 2016 and 2017 fish landings fetched MKW 129.74 billion (approx. US$ 172.74 million) and MKW 173.04 billion (approx. US$ 235.74 million) respectively. Apart from edible fish, Malawi also exports ornamental fish. In 2016 and 2017, Malawi ornamental fish sales fetched MKW 157.99 million (approx.US$222,280) and MKW 167.17 million (approx. US$228,863) respectively (GoM 2018). These figures display no significant difference in fish sale volumes for

ornamental fishes between the two years. In the same period there was an increased per capita fish supply from 10.7 to 12.5 kg per person per year (GoM 2018). This is a significant increase, particularly when compared to ten years ago when the supply was below 6 kg per person per year (Jamu & Chimatiro 2005). However, these improvements are questionable because recent fishing effort has been rising with the increasing population, while fish stocks are simultaneously being either fully or over exploited (Weyl *et al.* 2010; Tweddle *et al.* 2015). Over exploitation of fisheries is also reflected across Africa (Brummett *et al.* 2008). Therefore, caution must be taken to sustain fish provisions which requires an evaluation of other alternative livelihood sources, including intensification of fish farming.

Intensification of fish farming could be a viable alternative livelihood source. Aquaculture in Malawi is still at an early stage of development. However, it has potential at both small-scale and at commercial levels (FAO 2005). Aquaculture production increased from 2 578 metric tons in 2013 to 8 624 metric tons in 2017, which was valued at US$ 23.5 million (GoM 2018). The sector is still dominated by many smallholders participating at a similar scale to capture fishers. Malawi's aquaculture sector is also challenged by low quality production inputs (feeds and fingerlings) and institutional factors, which are supposed to support the innovation (Hecht & Maluwa 2005). These challenges are also similar in many other African countries (Brummett & Noble 1995; Brummett 1999; Brummett & Williams 2000; Brummett *et al.* 2008). However, in Malawi there has been a significant amount of research conducted by government agencies, which have still not been shared beyond experimental sites to the fish farmers (World-Bank 2000). Similar to aquaculture, the research focus within Malawi fisheries has also been centered on fish biology instead of social aspects (Ferguson *et al.* 1993; Derman & Ferguson 1995; Haraldsdottir 2002).

While there is an urgent need to look at social aspects of fisheries, examining the effects of climate change is equally important. Despite evidence suggesting that warming, nutrient fluxes, and water levels influence fish stocks in Lake Malawi (Owen *et al.* 1990; Bootsma & Hecky 1999; Vollmer *et al.* 2005; Chavula *et al.* 2009), but there is a lack of evidence to support whether the dwindling fish stocks is due to climate related impacts. Elsewhere, fish distribution and production decline has been attributed to the effects of climate change (Cochrane *et al.* 2009; Brander 2010). Evidence of climate change in Malawi is prominent (McSweeney *et al.* 2010) causing Lake Malawi's water temperature to increase (Vollmer *et al.* 2005). Increased water temperature affects the availability of food for fish in Lake Tanganyika (O'Reilly *et al.* 2003). There has also been some attempts to study the effects of climate change on Malawi fisheries at Lake Chilwa (Jørstad & Webersik 2016;

Nagoli & Chiwona-Karltun 2017). While these studies are important, they cannot be generalized to reflect other systems in Malawi because climate change impacts are context-specific and vary among communities, social groups and over time (Smit & Wandel, 2006). Fish catches and fishing activity are, however, known to mirror climate fluctuations (Jul-Larsen *et al.* 2003; Jamu *et al.* 2011). Therefore, there is a need to understand how fishers perceive the changes they are experiencing in relation to both climate and fish catches as well as how they are coping with such changes.

Problems related to managing open access natural resources like Lake Malawi can worsen under the pressure of global environmental changes. Climate change could also potentially accelerate the gap between the richest and the poorest, where women are among the poorest and most disadvantaged demographic (Lambrou & Piana 2006). It is also widely acknowledged that climate change impacts are gendered. Fishing in Malawi is mainly a man's job (McCracken 1987; Haraldsdottir 2002; Nakayama 2008; Nunan *et al.* 2015) with the exception of a few tribes in the northern part of Malawi, where the Nyakyusa women sometimes fish (Ferguson *et al.* 1993). However, the fish post harvest value chain is fully controlled by women, and women can also own fishing boats and nets (Haraldsdottir 2002; Hara & Jul-Larsen 2003).

The gender-differentiated impacts of climate change are, thus, directly linked to gender differentiated vulnerabilities, coping and adaptation strategies (Kakota *et al.* 2011; Field *et al.* 2014). Thus, future climate change impacts have the potential to disproportionately negatively affect poor people in low-income countries by altering their livelihoods and jeopardizing efforts to reduce poverty (Olsson *et al.* 2014). Unless gender inequalities are addressed and needs among the poor are met, climate-resilient development efforts will have marginal effects on livelihoods and food insecurity. Moreover, taking preventive measures well in advance has more benefits than reacting to unexpected catastrophes. It is important to consider sectors of production such as fisheries, in terms of the division of labour between women and men, and to identify the different degrees of vulnerability of women and men to the negative effects of climatic events. This enables policy-makers to put measures in place to combat environmental degradation, with the aim of minimizing the vulnerability of the women and men affected by them (Denton 2002). Hence, evaluating the effects of fluctuating fish stocks and adaptive capacity of Lake Malawi fishers would be less meaningful if gender was not considered.

While it is important to evaluate the vulnerability context of small scale fisheries due to impacts of climate change, assessing the connection between adaptive capacity and development initiatives is

also very important. As fisheries are characterised by unsustainable exploitative methods as a response to changes in fish catches, the role of development initiatives in reducing vulnerability is analysed. Currently, there is a lack of information to determine whether development initiatives enhance adaptive capacity in the face of global environmental changes. These initiatives are implemented in response to other stressors which do not include extreme weather events. However, other studies have found the initiatives to have potential positive impacts on enhancing adaptive capacity to climate related stresses (Agrawala & Van Aalst 2008; O'Brien 2012). At present, little empirical research has completed on vulnerability of Lake Malawi fishing communities. This knowledge is vital in designing climate change adaptation related policies.

2. THE OBJECTIVES OF THE THESIS

In order to provide evidence for possible implementation of climate change related policies, this thesis was mainly framed to explore how Lake Malawi fishing communities cope with changes in fish catches and their environment. To achieve these aims, four interlinked specific objectives and associated research questions are presented below:

1. To explore the effects of perceived climate change on Lake Malawi's small scale fishers and the determinants of their coping strategies.
    a. What are the perceptions of fishers on the changing climate?
    b. What are the effects of perceived climate change on the fishers' livelihoods?
    c. What are the fishers' coping strategies to the perceived climate change?
    d. What factors drive the fishers' coping strategies to the perceived climate change?

2. To examine gender roles on fish value chain, livelihoods patterns, and coping strategies for Lake Malawi's small scale fishers under the influence of climate related change.
    a. Do women and men in fishing communities perceive changes in weather trends and ecosystems differently?
    b. Do men and women perceive changes in fish catches and species composition differently?
    c. To what extent can changing gender roles in the fish value chain be attributed to climate change?
    d. Has a shift in household livelihoods been observed over the past 20 years?
    e. Do women and men in fishing communities employ different strategies to cope with climate change?

3. To examine the status of fish farming and its feasibility as a livelihood strategy for Lake Malawi's smallscale fishers.
    a. What are the socio-economic characteristics of the fish famers?
    b. What is the status of the fish farming food system?
    c. What are the effects of extreme weather events on fish farming?
    d. What are the outcomes of food systems for the fish farmers?

4. To explore development initiatives, livelihood assets and adaptive capacity among Lake Malawi fishing communities.
    a. Who are the households that benefit from different development initiatives?

b. Which of these initiatives possess potential in building adaptive capacity?
c. How does adaptive capacity relate to net income and income distribution?
d. What are the problems of targeting and selection bias for development initiatives using cross-sectional data?

These objectives and associated research questions are broad, however this thesis assessed them in the context of Malawi fisheries.

3. MALAWI FISHERIES

3.1 Description of major water bodies

Fishing in Malawi is conducted in lakes, rivers, and floodplains which cover about 23% of Malawi's total area (Figure 1). One such water body is Lake Malawi, also called Lake Nyasa or Niassa, which is Africa's third largest lake with a size of 28,000 km^2, volume of 8,400 km^3, a maximum depth of 785 m, a mean depth of 292 m, and a retention time of 750 years (Patterson & Kachinjika 1995). It is 550 km long, 50–60 km wide, and lies at 427 m above sea level.

Figure 1. Map showing position of Malawi and its major water bodies.

Lake Malawi is environmentally "stable", with a low relative lake level fluctuation index (Jul-Larsen *et al.* 2003) and has close to 1000 endemic fish species (Turner *et al.* 2001). Its South-east arm is shallow and is the most productive. As such, there is immigration of fishers to this part of the lake (Derman & Ferguson 1995; Chirwa 1996; Haraldsdottir 2002). The northern parts of Lake Malawi are deep and surrounded by steep rocks (McCracken 1987). This makes fishing there difficult and could be the reason why many Tumbukas and Tongas fishers who are originally from the north have settled near the southern parts of the lake. However, migrant fishers lack land to conduct farming (Ferguson *et al.* 1993; Haraldsdottir 2002). Artisanal fishers contribute more than 90% of fish catches from this water body, compared to less than 10% by commercial fishers (GoM 2018).

The other main water body is Lake Malombe, which is 390 km^2 and lies at the outflow of Lake Malawi through the Upper Shire River. Its average depth is 5–7 m with a maximum depth of around 17 m. This lake is a featureless open water body where small scale fishing started in the 1960's after the decimation of a large crocodile population (van Zwieten *et al.* 2003). The water levels of both Lakes Malawi and Malombe are regulated by a dam on the Shire River at Liwonde, south of Lake Malombe. Unlike Lake Malawi where commercial fishers are allowed, Lake Malombe is only exploited by artisanal fishers. In 2017, the total catch at Lake Malombe was 4, 663 tons (GoM 2018). Two important events associated with this water body are the collapse of its Chambo (*Oreochromis spp.*) fishery in the 1990s due to overfishing (Weyl *et al.* 2004) and thereafter the pilot introduction of a formalized participatory fisheries management regime (Bell & Donda 1993; Russell *et al.* 2008a).

Another water body where extensive fishing is conducted is Lake Chilwa. It is the second largest lake in Malawi and is "greyish, turbid, often turbulent, less than 5 m deep and is almost 2, 000 km^2 in area at the end of the wet season when in floods" (Kalk 1979). Lake Chilwa is located in the southern part of Malawi. Lake Chilwa is one of the most productive lakes in Malawi due to its shallow depth (van Zwieten & Njaya 2003). This lake has no outlet and has dried out nine times since the 1900s, most recently in 2012 (Nagoli 2016). As a result of its geography, fish stocks fluctuate in response to water levels. This lake is also shared with Mozambique just like Lakes Chiuta and Malawi. Lake Chilwa is mostly fished by small scale fishers with the year 2017 total fish catch at 3, 270 tons (GoM 2018).

Lake Chiuta is another shallow lake similar to Chilwa, but with an average depth of 5 m. Its total surface area is 200 km^2, of which 49 km^2 lie in Mozambique (FAO 1994). Its southern part has

emergent vegetation that is penetrable by canoes, but not by larger vessels (Njaya *et al.* 1999). The total fish catch from Lake Chiuta in 2017 was 1,493 tons (GoM 2018).

Despite the lakes facing challenges in proving fish for the growing population, rivers and floodplains are also part of fisheries in Malawi where small scale fishers access their livelihoods. The majority of riverine fish species in Malawi migrate to major lakes after breeding in the river (Tweddle 1983). The major rivers where fishing is done include: Shire (Tweddle *et al.* 1979; Chimatiro 2004; Ngoma 2010), Likangala (Jamu *et al.* 2003), Linthipe (Zidana *et al.* 2007; Limuwa *et al.* 2013; Limuwa *et al.* 2014), Bua (Chigamba *et al.* 2012; Matsimbe 2012), Dwangwa (Tweddle 1992), North Rukuru, and South Rukuru (Tweddle 1983). Despite the importance of riverine fisheries, farming is conducted in the riverbanks, taking advantage of residual moisture (Mkanda 2002; Zidana *et al.* 2007). Some of the riverine fish catches have been impacted by siltation and rivers drying up. These different types of water bodies and ecosystems makes it difficult for a "one size fits all" fisheries management policy in Malawi (Jamu *et al.* 2011) due to their unique characteristics.

3.2 Fisheries development

The 'one size fits all' notion of managing water bodies does not historically reflect development of naturals resource that are mostly sustained through donor aid. Even though Non-Governmental Organizations (NGOs) and donor agencies have no official mandate to develop and manage Malawi fisheries, their commitment in terms of funding, research, policy direction, and community engagement cannot be ignored (Russell *et al.* 2008a). Additionally, fisheries development relies on the growth and technical advancement of the fishery sector. This is not the case with the people-centered Malawi fisheries when compared to developed countries where fisheries are industrialized (Seymour 2001). But development of the Malawi fisheries sector has been shaped around three questions: "who controls fish resources, who has the authority to determine the development of the fishing industry, and who has the right to allocate plots of land along the lakefront for non-fishing purposes?" (Chirwa 1996).

These questions are framed based on the fisheries resource being open access, which makes it difficult to claim or enforce any exclusive rights to a water body. For example, since its formation, the Lake Malawi hasn't had any tenure rights allocated to any person or company. This allows lakeside communities to have unlimited access to the lake making it their main livelihood source. However, in the 1920's there was a transformation of the fishers from entirely African to European and Asian as well when commercial fishing began. This angered some local chiefs who reported

the matter to the colonial government. The chiefs claimed that their rights were being infringed upon. Furthermore, some of those Europeans and Asians were financing African fishers and fish traders on the sidelines (McCracken 1987). Despite laws restricting intensification of fishing by foreigners, the bans were not abided. The current non-compliance to fish regulations (Hara & Njaya 2016), thus, are not entirely new. For example in 1931, fishing regulations barred Europeans and Asians from areas fished by Africans. However, the colonial government did not have the capacity to enforce such regulations. Instead, the colonial government promoted African fishing as a mechanism to reduce the number of tax defaulters, as most areas around Lake Malawi were not fit for agriculture. As such, fishing was the only money making activity available. Therefore, fisheries in Lake Malawi have remained dominated by traditional fishing practices unlike other neighboring countries where fishing is highly mechanized and developed (Chirwa 1996).

Recently, there has been a push to develop Malawi fisheries with sophisticated equipment. This advancement could result in more than 1.6 million people who are currently employed in the fish value chain to lose their jobs. Despite the current situation, the number of fishing crafts (dugout canoes and planked canoes) has been increasing (Ferguson *et al.* 1993; GoM 2015a; GoM 2018). Mechanization could also intensify competition between the small scale commercial fishers and semi and full scale commercial fishers as evidenced in the southern part of Lake Malawi (Haraldsdottir 2002).

This quest to develop Malawi fisheries was further subjected to neo-liberal dealings championed by the World Bank. For instance, the Department of Fisheries (DoF) used to sell recommended fishing gear, plank boats, motor equipment repairs, ice, and provide fish processing facilities. These have all since become privatized (World Bank 2000). This shift might explain the current influx of illegal fishing gears (Limuwa *et al.* 2018), as private traders seek to maximize profits where the fishers also wish to maximize catches by the use of non-size selective gears (Haraldsdottir 2002). The withdrawal of government service provision functions significantly affected the performance of the fisheries sector (Seymour 2001), due to conditionalities attached to loans from the World Bank (World Bank 2000).

Efforts to develop fisheries must be based on relevant documentation and consideration of the local context. Development initiatives aimed at increasing Lake Malawi fish catches have been varied. For instance, a World Bank funded Project in the early 1990s had to suspend a component of its project on fish catch enhancement because of a United Nations' Food and Agricultural

Organization (FAO) report on a Chambo project that had cited overfishing. However, the aforementioned overfishing was only concentrated in one area of the lake (World Bank 2000). Another fisheries project funded by the African Development Bank targeting small scale fishers was implemented in the early 2000s with an objective of increasing fish production by 21,000 metric tons by end of the project in 2008. However, it failed to reach that target (ADF 2002; GoM 2016). Moreover, the objectives of such projects were incongruous with the needs of the fishing communities. For example, female's access to credit intended for fish processing and trading was instead used for other businesses (World Bank 2000). This failure could be attributed to the inability to understand the targeted social groups prior to implementation of the project (Ferguson *et al.* 1993; Haraldsdottir 2002). These examples of development projects have revealed the importance of assessing the needs of the local communities, as opposed to the donor appeasing political rhetoric used by developing countries (Chinsinga 2003).

While development efforts are generally viewed positively by local communities; forest reserves, national parks and large sugar cane plantations along Lake Malawi's ecosystem have rendered people landless. This form of development further restricts local communities' ability to fish and access other forms of livelihoods (Derman & Ferguson 1995). Furthermore, pesticide usage in such plantations have the potential to harm people, water, and fish (Donga & Eklo 2018). Additionally, in other areas along Lake Malawi such as Nkhotakota district, the majority of the land is inaccessible, denoted as either game or forest reserves in addition to the large proportion of sugar plantations (GoM 2010). Therefore, even if fishing communities would like to expand their livelihood base through farming they might have challenges to obtain the needed land. Such cases are also similar in many other African countries such as Tanzania, Kenya and Uganda (Benjaminsen & Bryceson 2012; Petursson *et al.* 2013; Tumusiime & Sjaastad 2014; Tumusiime & Vedeld 2015), where establishment of conservation or protected areas has negatively affected local communities' livelihoods.

3.3 Fish catch trends

Artisanal fishers contribute to over 90% of the total fish catches in Malawi and are not restricted to any locations unlike the semi commercial and commercial fishers (GoM 2018). The large-scale commercial sector is highly mechanized and capital intensive but their fishing effort and location is restricted to certain areas (Ferguson *et al.* 1993; Haraldsdottir 2002). Catches by Lake Malawi small scale fishers reveal fluctuating fish catch trends. This pattern is common in many African water bodies whose fish stocks are highly affected by the climate, as observed in Lake Chilwa (Allison *et al.* 2001). Studies conducted in several southern African countries, including Malawi,

indicate that an increase in fishing effort does not affect total biomass when compared to environmental factors. The exception occurred when fishing gear efficiency was improved (Hara & Jul-Larsen 2003; Jul-Larsen *et al.* 2003). Despite the health of Lake Malawi fisheries worsening over time as evidenced by trophic level deterioration (Nsiku 1999), the total fish catches seem to be stable, with fluctuations in species composition. For example, the proportion of species such as Usipa (*Engraulicypris sardella*) fluctuates, and previously important species like Chambo (*Oreochromis spp.*) no longer dominate (Nsiku 1999; Palsson *et al.* 1999; Haraldsdottir 2002; Limuwa *et al.* 2018). These trends illustrate the complexity of population dynamics in these water bodies.

Such fish catch fluctuations could have an implication on understanding Lake Malawi's fish population structure which might suggest a shift from *K selection* to *r selection* (Pianka 1970) due to unstable population size, rapid development, small body sizes, and early maturity at small size. There are multiple factors that could result in these fluctuations such as climate variations (Bone & Moore 2008; King 2013), overfishing inflicted by the need to survive by individual fishers, silting of spawning grounds and rivers, and loss of spawning areas (Banda *et al.* 2005) amongst others. Due to the fluctuation of fish catches, Malawi fisheries' ecosystems could be deemed vulnerable and poorly understood.

3.4 Aquaculture

The advent of fish farming in Malawi occurred to supply fish to inland areas, previously unreachable because of poor road infrastructure to transport fish from the major fishing grounds to feed the growing population (Bertram *et al.* 1942 cited in Russell *et al.* 2008b). Currently, fish farming intensification occurs in response to fluctuating fish catches from natural water bodies. Fish farming in Malawi is in its early stages, despite fish culturing being practiced for more than 100 years (Kalinga 1991). Malawi has developed comprehensive guidelines to help potential farmers, specifically in pond fish farming on the best geographical areas and conditions. These guidelines are aimed to benefit both producers and consumers (Russell *et al.* 2008b).

More than 15% of land in Malawi has potential for aquaculture. Fish farming contributes to 10% of the total household income while the proportion of agriculture-based income is more than 50% (Andrew *et al.* 2003; Dey *et al.* 2010). There is potential to expand fish farming, however, such expansion over relies on funding from NGOs and donor agencies who feel that the large investments in fish farming have failed to achieve the desired impact (Russell *et al.* 2008b). This potential is not hindered by access to land resources, but by reliable water supply, and possibly, impacts of climate change. Fish farming in Malawi is mainly conducted by small scale farmers in

earthen ponds that vary in size depending on production capacity. The culturing system is mostly integrated within agriculture to increase resource flows (Brummett & Noble 1995). Small scale aquaculture has boomed in many areas of Malawi (Maluwa & Gjerde 2007) and currently there are 15, 465 fish farmers tending to 10, 007 fish ponds. Most of these fish farmers are in Mulanje, Nkhotakota, and Phalombe. Conversely, most ponds are in Zomba, Mulanje, and Nkhatabay (GoM 2018).

Commercial aquaculture entities have been introduced in Kasinthula, Mangochi, and Salima. The culturing units in Kasinthula are earthen ponds while Salima and Mangochi companies use cages suspended in Lake Malawi. Production levels of the Mangochi company, were lower than anticipated in its earlier years of inception (Windmar *et al.* 2008). Elsewhere, other fish culturing systems such as small cages in Lakes Malawi, and Chikukutu, and Chia lagoon were piloted and failed due to climate related issues and poor fish growth (ibid).

Common fish species cultured in Malawi include *Oreochromis shiranus, Oreochromis karongae, Tilapia rendalli, Clarius gariepinus*, *Cyprinus carpio*, *Micropterus spp*., and *Oncorhynchus mykiss*. However, *Tilapia rendalli* changed its genus to *Coptodon* (Dunz & Schliewen 2013; Skelton 2016) and for the sake of this thesis, its old name was used. The majority (>90%) of fish production in Malawi is from tilapia species, while the remaining 10% consists of exotic species (Hecht & Maluwa 2005). Exotic species (*Cyprinus carpio*, *Micropterus spp*. and *Oncorhynchus mykiss*) are confined to geographically isolated areas due to the restriction of movement of alien species (GoM 1997). Despite such restrictions, these species exhibit more desirable traits compared to the indigenous species, such as high growth and breeding rates (Hecht & Maluwa 2005).

At the smallholding level, challenges also exist in establishing profitability of fish farming because of the lack of records on the number of fish stocked and harvested. This is mostly attributed to low levels of education among other factors. Inability to access extension, quality fingerlings, and feeds also hinders production levels for fish farming (Andrew *et al.* 2003). Therefore, recommendations to promote other participatory methods for disseminating fish farming have been made due to less Department of Fisheries (DoF) extension agents on the ground. These methods include farmer to farmer and the use of fish farmers' clubs (ibid). Malawi's fish farmers are also known to be involved in other farming enterprises such as agriculture. In addition, fish farmers who register high levels of fish production are consequently more productive farmers

(Russell *et al.* 2008b). However, most fish from the small scale fish farmers are sold as fresh fish at or near their locality (Andrew *et al.* 2003).

In summary, many studies have been conducted on the potential of fish farming. These studies included screening for potentially fast growing species requiring less inputs. Despite such efforts, Malawi's local species are labelled as slow growers, and increase costs associated with feeds within the production system. With many studies focused on both fish biology and social aspects of the farmers, one would expect to see a sharp rise in fish production, but that is not the case. Fish production from aquaculture remains very low, with current production levels are at 8,624 metric tons per year (GoM 2018). Fish farming operations are not mechanized and have limitations on the allowable size of fish culturing facilities. In general, Malawi fish ponds are below the threshold for yield maximization (Russell *et al.* 2008b).

3.5 Malawi fisheries legal framework

Fishing, rearing fish, and all other activities in Malawi's water bodies are governed by the Fisheries Conservation and Management Act (GoM 1997). This act works together with other pieces of natural resources legislation. The first specific fisheries legislation was enacted in 1973 after the formation of the current fisheries department in 1971. "These regulations are contained in the Fisheries Act in the Laws of Malawi, Chapter 66:05 1974 and were amended or supplemented in 1976, 1977, 1979, 1984, 1996 and 1997"(Nsiku 2001). The legislation among other things, deals with local community participation, aquaculture, and international cooperation in fisheries, prohibition, and offences. Furthermore, the current legislation supports the implementation of the National Fisheries and Aquaculture Policy (NFAP), which is framed to respond to issues affecting fisheries and aquaculture development in Malawi.

The current policy is a second edition of the original 2001 policy. These policies have a life span after which certain revisions have to be made to reflect changes in the sector (GoM 2016). The NFAP is also framed in connection with Malawi's overarching development objectives of "Building a productive, competitive and resilient nation", as outlined in the Malawi Growth and Development Strategy (MGDS) III (GoM 2017). Furthermore, NFAP takes key agreements and protocols into account including the Southern Africa Development Community (SADC) Protocol on Fisheries; the Abuja Declaration; the Convention on Biodiversity and its subsidiary protocols which commits Malawi to the preserve biodiversity; the FAO Code of Conduct for Responsible Fisheries (FAO 1995), and the Ecosystem Approach to Fisheries Management (GoM 2016).

Despite these considerations, NFAP is still weak as it remains silent on addressing fishers who have flexible coping strategies to low fish catches, including geographical and occupational migration. Perhaps such weaknesses will be addressed in the districts' decentralized bylaws (Allison *et al.* 2001). The other weakness of the policy is that it does not reflect how it intends to cooperate with other sectoral ministries in managing water bodies, although it does mention that its framing took such aspects into consideration. This oversight has long-term implications on the sustainability of the fisheries resource. For example, there are multimillion dollar projects within Lake Malawi ecosystem including: oil exploration, channeling water for household usage to Malawi's capital city; channeling water for irrigation in large sugarcane plantations, and other irrigation schemes along the lakeshore. At the same time the lake is used as a method of transport along the lake shore districts and islands located in Lake Malawi (GoM 2017). These issues require multi-sectoral policies to be aligned to sustainably manage these ecosystems (Ngochera *et al.* 2018).

3.6 Fisheries management system

Although Malawi has the legislation and several relevant policies needed to guide natural resources management, it has no comprehensive framework to assess the management of its water basins, expect for the integrated catchment management that excludes fisheries experts in catchment management and planning (GoM 2015b). Therefore, there is an increasing need for such a framework to guide the formulation of management plans and strategies (Chidammodzi & Muhandiki 2016). Malawi's fisheries management system used to be "top down" (van Zwieten *et al.* 2011). This management was informed through long-term monitoring of catch rates and fishing effort (Bazigos 1974) and was based on quantitative models that set targets for fish stock management. However, the level of financial and human resources allocated for such tasks was small (Darwall & Allison 2002). Due to this, further questions can be raised relating to how close to the truth are such reference targets. These assessments are also limited to few sections of the exploited ecosystem (van Zwieten *et al.* 2011). Although fishing is open access, there are other management controls, which are also institutionalized. These include an annual gear licence fee, gear types and mesh size regulations, fishing times, and fishing area restrictions in nursery grounds (Ngochera 2001; Darwall & Allison 2002).

However, in order to mitigate these challenges associated with setting unrealistic target reference points, Malawi adopted a participatory fisheries approach (co-management). This change was a response to the "top down" management, which failed to regulate fishing and caused the overexploitation of major fisheries like Lake Malombe. As a result, in 1993 Malawi Government adopted a participatory fisheries management approach. This approach started before any

successful fisheries co-management regimes had been documented in Africa and was based on a rough theoretical framework (Bell & Donda 1993; Dawson 1997). This new approach was supported through projects funded by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) for a period of 10 years. These projects also spearheaded the creation of a legal basis for fisheries policy to empower the implementation of the new approach (Dobson & Russell 2001; Weyl 2008). Furthermore, the Fisheries Conservation and Management Act was reviewed to include these management changes (GoM 1997). The management of fisheries resources is now entrusted to elected Beach Village Committees (BVCs) who work hand in hand with the Department of Fisheries. This new approach is hinged upon scarce resources provided by the government to manage fisheries, but it also values the knowledge and involvement of local stakeholders who are the primary beneficiaries of the resource (Nsiku 2001).

Despite positive results in its early years which increased fish catches in Lake Malombe, fisheries devolution failed, and was seen as a patchwork that could be deemed "de facto adaptive management". This is so because there are several systems for managing Malawi fisheries in practical terms despite legislation regarding participatory approaches. These approaches are geared towards improving the natural biomass. However, lack of local legitimacy undermines the processes of participatory approaches as the regulations do not factor in the local needs of the people, but instead are more protectionist (Russell *et al.* 2008a). For example, the Department of Fisheries (DoF) undermined the authority of the BVCs in implementing co-management. It was difficult for the Department of Fisheries to let go of some of their regulatory powers due to their strong relationship with commercial and semi-commercial fishing industries (Bell & Donda 1993; Dobson & Russell 2001; Haraldsdottir 2002; Dobson & Lynch 2003). Another challenge associated with the co-management, was the lack of instruments in the districts to enforce their mandate. This was rectified by instituting district fisheries bylaws, which empowered the BVCs (Balarin 2001). However, before Malawi's 2014 tripartite elections, there was a vacuum of power in the District Assemblies, which made passing and enforcing these bylaws a challenge. However, these challenges and strategies to mitigate fisheries governance problems have been factored into the current National Fisheries and Aquaculture Policy (GoM 2016), which has been informed by scientific research (Dobson & Russell 2001; Dobson & Lynch 2003; Hara 2006; Njaya 2007b; Njaya 2007a; Hara 2008; Jamu *et al.* 2011; Njaya *et al.* 2012; Hara & Njaya 2016).

Nkhotakota district along Lake Malawi passed its participatory fisheries management bylaws in May 2018. These empower the local communities through section 103 of the Local Government

Act 1998 to manage their natural resources (GoM, 2018b). These bylaws have given the Area Fisheries Association legal powers to sue and be sued. These bylaws however restrict short-term migrant fishers, as stated "No person shall be allowed to fish without a local permit (only available to local fishers who live in the area all the year)". However, the licensing role has been maintained by the DoF. These bylaws also restricts cultivation in buffer zones i.e. area of land designated for environmental protection within 50 to 100 m from water bodies. Some aspects extracted from part 4 of the bylaws state the following:

a. All Local Fisheries Management Area (LFMA) will have a maximum number of permits (or shares) for their area based on the size of the landing site and ecosystem management plan. The number of permits allocated to each cannot be exceeded nor traded.
b. All local fines will be paid to the LFMA for reinvestment into local fish conservation projects as agreed by the Fisheries Association and proper accounting records must be maintained.
c. If fines are not paid within two weeks to the LFMA, the defaulter will be liable to prosecution.
d. If the offence is fishing with illegal gears, within the closed season, in prohibited (breeding) area or prohibited fishing method and appeals [sic] these District Bylaws, then they will be prosecuted under the powers of the Fisheries Conservation and Management Act.

In summary, these bylaws have restricted movement of fishers from other areas into Nkhotakota. However, enforcing such regulations on offshore fishers will be not be practical. This might also put livelihoods of migrant fishers in danger. While these bylaws might restrict entry of non-Nkhotakota fishers, however Nkhotakota fishers are free to migrate to other areas that have weak or no bylaws. These shortfalls are an example of how these bylaws will be tough to implement.

In addition to local bylaws, Malawi has also adopted the Ecosystems' Approach to Fisheries and Aquaculture (EAFA) as a framework to aid implementation of co-management (GoM 2016). However, the process of setting objectives in the EAFA development is hampered by a lack of human resources and inadequate and unreliable data for analysis. Lack of data on the impact of climate change on Malawi fisheries and its interplay with livelihoods has also derailed implementation of the EAFA (Njaya 2016). Because small scale fishers over-rely on fish for their livelihoods, therefore application of EAFA could be also tough. However, the EAFA combined with a rights based management approach, could provide a sustainable fisheries management (Hara & Njaya 2016).

Even with such a background on Malawi fisheries, there remains a lack of information on how fishers are adjusting to the additional effects of exposure to extreme weather events. Furthermore, there is lack of climate related studies relating to social aspects of fishing communities to the fishing itself. These questions are not exclusive to Malawi but also to other water bodies with similar characteristics to those in Malawi. Therefore, this thesis fills an important knowledge gap beyond one single body of water and its related communities.

4. CLIMATE TRENDS FOR MALAWI

While it is important to fill the knowledge gaps on how climate is affecting fishers' livelihoods, assessing these climate trends is paramount. Coping with climate change and its effects on fisheries could be successful through developing management systems and monitoring the ecological systems to detect changes (Paukert *et al.* 2016). This, however, should be a cause for concern for southern Africa, which is characterized by a highly variable climate (Mason *et al.* 1996; Nicholson & Kim 1997; Watson & Albritton 2001; Nicholson *et al.* 2014). Countries within this region such as Malawi are vulnerable to extreme weather events (Allison *et al.* 2009; Saka *et al.* 2012; USAID 2013). However, climate change discourse in Malawi has been shaped through development partners' funded programmes.

Development agents and international development organizations have significant economic and political power in Malawi (Haraldsdottir 2002). Malawi is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) treaty and many other conventions aimed at reducing emissions while improving mitigation and adaptation. However, due to its overdependence on donor aid, there are conditionalities to accessing aid tied to ratification of such treaties. Failure to do so is tied to threats of aid cuts, as some aid is inaccessible without first being a signatory to climate related treaties (GOM 2002; GoM 2006; GoM 2012a; GoM 2012b; GoM 2013). This also affects what could be deemed climate change, as in many cases people are confused between climate change or climate variability (Simelton *et al.* 2013; Limuwa *et al.* 2018).

Despite many studies on climate change in Malawi, little research relating these changes to the impact on fishers' livelihoods has been completed (Kalanda-Joshua *et al.* 2011; Ngongondo *et al.* 2011a; Ngongondo *et al.* 2011b; Simelton *et al.* 2013; Nkomwa *et al.* 2014; Nagoli 2016). However, the effects of some limnological parameters on fish catches can easily be tied to environmental changes (Kalk 1979; Owen *et al.* 1990; Patterson & Kachinjika 1995; Bootsma & Hecky 1999; Chifamba 2000; Msiska 2001; Mkanda 2002; Bootsma & Hecky 2003; Hecky *et al.* 2003; Chimatiro 2004; Chavula *et al.* 2009; Kolding & van Zwieten 2012). These studies, however, lack the social dimension on their effects to the livelihoods of the fishers.

Malawi's projected trends for temperature and precipitation using different Global Circulation Models (GCMs) and climate scenarios are presented in Table 1. The table indicates increased temperatures and variable precipitation. These projections suggest that Malawi food production systems, which rely on rainfall, could be vulnerable.

Table 1: Temperature and precipitation projections for Malawi from 1979 to 2100s using different Global Circulation Models (GCMs) and climate scenarios.

Coverage in Malawi	Predicted Years	Climate Scenario	Future prediction		Reference
			Temperature	Precipitation	
Whole country	2030s	A2	from 0.9 to 1.7°C	from – 8 to 9%	(McSweeney *et al.* 2010)
Whole country	2060s	A2	from 1.7 to 3.0°C	from -9 to 14%	
Whole country	2090s	A2	from 3.1 to 5.0°C	from -10 to 32%	
Whole country	2020 - 2050	A1B	from 1.1 to 3.0°C	from 200 to 400mm	(Saka *et al.* 2012)
Mzimba	2040 - 2070	RCP 8.5	from 1 to 3°C	-1.40%	(Gama *et al.* 2014)
Northern region	2020 - 2050	A1B	from 1.5 to 2°C	from 50 to 100mm	(Saka *et al.* 2012) (Phiri & Saka 2008)
Central region	2020 - 2050	A1B	from 2.5 to 3°C	from 200 to 400mm	
Southern region	2020 - 2050	A1B	from 2.0 to 2.5°C	from 50 to 200mm	
Shire Valley	2100s		4°C	decreased by 2 - 8%	
South - Shire Valley		$2xC0_2$	From 2.8 to 3.1°C	-1.10%	(Mkanda 1996)
South - Shire Valley	1979/80 1991/92		From 3.1 to 3.8°C	from -8.26 to 17.23%	(Mkanda 1999)
Central - Lilongwe	2020s	RCP 8.5	from 0.7 to 0.8°C	from - 7.3 to - 0.4%	(Stevens & Madani 2016)
Central - Lilongwe	2050s	RCP 8.5	from 1.6 to 2.3°C	from - 2 to 11%	
Central - Lilongwe	2080s	RCP 8.5	from 2.1 to 2.3°C	from - 12.3 to - 1.9%	
Central - Lilongwe	2046 -2065	A2	from 1.8 to 2.6°C	from - 9 to 7%	(Zinyengere *et al.* 2014)

For example, yields of Malawi's staple food, maize, were projected using weather data estimates from 2010 to 2030 generated by RegCM4 using the A1B scenario and showed increased yields in maize–cowpea rotation compared to conventional tillage (Ngwira *et al.* 2014). Similarly for other crops like rice, Daccache *et al.* (2015) predicted an increase in yields for both rainfed and irrigated rice production. Rainfed and irrigated rice yields were projected to increase by 8% and 9% respectively. Furthermore, these projections have also shown that in Lilongwe district of Malawi, maize production could benefit in the short term from climate change with increased yields ranging from 4.6% to 5.4%, − 1.2% to 1.0% and − 3.0% to 0.2% in the 2020s, 2050s and 2080s respectively (Stevens & Madani 2016). However, Zinyengere *et al.* (2014) projected average decline in maize and groundnut by 5% and 33% respectively for the same Lilongwe district between 2046 and 2065. In contrast, in the Mzimba district in the northern region of Malawi, maize yields are expected to increase by 10 and 15 % between 2040 and 2070 (Gama *et al.* 2014). Saka *et al.* (2012) made projections for maize, cassava and other roots and tubers, as well as cotton for all of Malawi. In their paper, Maize production is projected to increase by over 15 % between 2010 and 2030,

whereas cassava production and other roots and tubers yields will increase by 50 percent and cotton production will be doubled by 2050.

Despite the projected increase in temperature and decrease in precipitation, crop yields for some staple crops like maize, rice, groundnuts, cotton, cassava, roots, and tubers are projected to increase. These projections show the inconsistencies between different GCMs and climate scenarios, questioning their reliability, which could be attributed to a lack of capacity to downscale climate models (Zulu 2017). However, there is potential to use such projections in planning for, adapting to, and mitigating climate change impacts.

Similarly, Malawi fisheries might have been impacted by climate related changes. For instance, rainfall affects catches and breeding of some fish species endemic to Malawi like *Opsaridium microlepis* (Tweddle 1983; Limuwa *et al.* 2013), *Engraulicypris sardella* (Jere *et al.* 2016), and *Oreochromis spp.* (Makwinja & M'balaka 2017). On the other hand, the water temperature of Lake Malawi has increased (Chavula *et al.* 2009). This affects the availability of food for fish due to water stratification (Vollmer *et al.* 2005). A similar water-warming situation was reported for Lake Tanganyika, another Great Rift Valley lake like just Lake Malawi (O'Reilly *et al.* 2003; Verburg *et al.* 2003). However, there remains a lack of models relating to inter-annual variability, decadal (regional) variability and global climate change with respect to Malawi fisheries. These models could improve planning for adaptation processes. However, not much of the input factors for modelling are known for Malawi, except for the variability of inter-annual rainfall (Ngongondo *et al.* 2011b) and temperature (Vollmer *et al.* 2005). However, Malawi's climatic system could be related to the North Pacific (Nicholson & Kim 1997), which is influenced by El Niño–Southern Oscillation (ENSO) (Easterling *et al.* 2007). In the North Pacific, ENSO causes regime shifts that impact fish distribution (King 2005). Therefore, there is a lack of knowledge on how these changes could impact Malawi fishing communities.

5. THEORETICAL FRAMEWORK

Fish are crucial to many people in Malawi and the current problem of low fish catches is over shadowed by narrative that high population is causing overfishing (Banda *et al.* 2005; Russell *et al.* 2008b). Other vulnerabilities connected to livelihoods are further increased due to stressors such as climate related exposures. This poses further challenges on the dilemma of sustainable conservation in light of continued reliance of fish as a food provision for much of the population (Nsiku 1999; Allison *et al.* 2002).

In this thesis, a small scale fisher is defined as one who either owns fishing gear, a vessel, or both (Haraldsdottir 2002). Internationally, there is not one single definition of a small scale fisher. The definition is governed by the context in which fishers operate (Pauly & Charles 2015). However, in most cases the fisher typology is dictated by fishing location, type of fishing equipment such as gear sophistication, vessel engine size, number of fishing crew employed, extent of marketing, operator's income level, and time commitment among others (Smith 1979; Thompson 1980; Berkes 2001). Malawi small scale fishers are often referred to as traditional or artisanal fishers but this is a wrong assumption because these fishers also sell any surplus fish to buy other basic necessities (van Zwieten & Njaya 2003; MacPherson *et al.* 2012; Chiwaula *et al.* 2018). Instead, Malawi fishers should be classified as small-scale commercial as suggested by Ferguson *et al.* (1993).

The process of defining boundaries and using certain concepts is crucial, especially in a complex field like fisheries where fishing communities interact with the ecosystem. These complexities not only deal with fishers and their ecosystem but can also include institutions. Therefore, a holistic framework is required for complete comprehension.

This thesis employed various concepts to understand how local communities along Lake Malawi sustain their livelihoods under the influence of different vulnerability contexts. Due to interactions between the fishers and their ecosystem, this thesis lays its foundation on several concepts and theories. The different theories used in this thesis are linked to approaches of households' current livelihoods at the study sites. These provide an understanding of the phenomena through which this thesis is framed. Despite the Sustainable Livelihood Framework (SLF) being the major conceptual framework in this thesis, other theories and concepts were also used to situate several aspects of the research. These included: vulnerability, Gender and Development (GAD), and sustainable food systems.

The SLF (Figure 2) is a dynamic approach which has been used by development agencies and researchers to understand livelihood profiles of poor rural communities under different vulnerability contexts (Chambers 1989; Carney 1998; Scoones 1998). It has also been used to understand local communities in Malawi (Orr & Mwale 2001). This approach revolves around assets or capitals which communities possess. These assets are divided into five broad types: natural, human, physical, social, and financial. These assets are the basis on which different livelihoods are built, substituted or complemented. Despite this framework being poor people oriented, it does not provide guidance in the identification of such groups of people. In addition, the framework does not take the households' culture or their leisure activities into consideration. Furthermore, the measurement and analysis of capitals and how they feeds into policies are additional challenges associated with SLF (Morse & McNamara 2013). This framework is also complex as evidenced through people's lives. Therefore, there could be huge costs related to focus, depth, and analytical clarity (Van Dillen 2002). Additionally, livelihood perspectives have been found to not address questions related to "knowledge, scales, politics and dynamics" (Scoones 2009). Morse and McNamara (2013) noted that most of these challenges could be mitigated by using the framework as an aiding tool. However, not all livelihood strategies depicted by the framework are sustainable. The arrows in Figure 2 do not necessarily imply causation but rather direction or flow of influence. The sections that follow highlight different components of the SLF and where the four interrelated studies were situated within the framework.

5.1 Vulnerability context

Understanding vulnerability context when using the SLF as a framework of analysis is the first step that provides information on available assets and vulnerability (Scoones 2009). Vulnerability is defined as the insecurity of individuals in the face of changing ecological, economic, and political environments in the form of shocks, long-term trends, or seasonal cycles (Moser 1998). Vulnerability research is influenced by three dominant fields: risk/hazard, political economy or ecology, and resilience (Eakin & Luers 2006). When vulnerability assessment is conducted as a starting point in climate change analysis, it places the social and economic well-being of the society at the centre of the analysis (Kelly & Adger 2000). Vulnerability assessments also improve adaptation planning and raise awareness of risks and opportunities while advancing scientific research (Patt *et al.* 2009). However, there are different frameworks for assessing

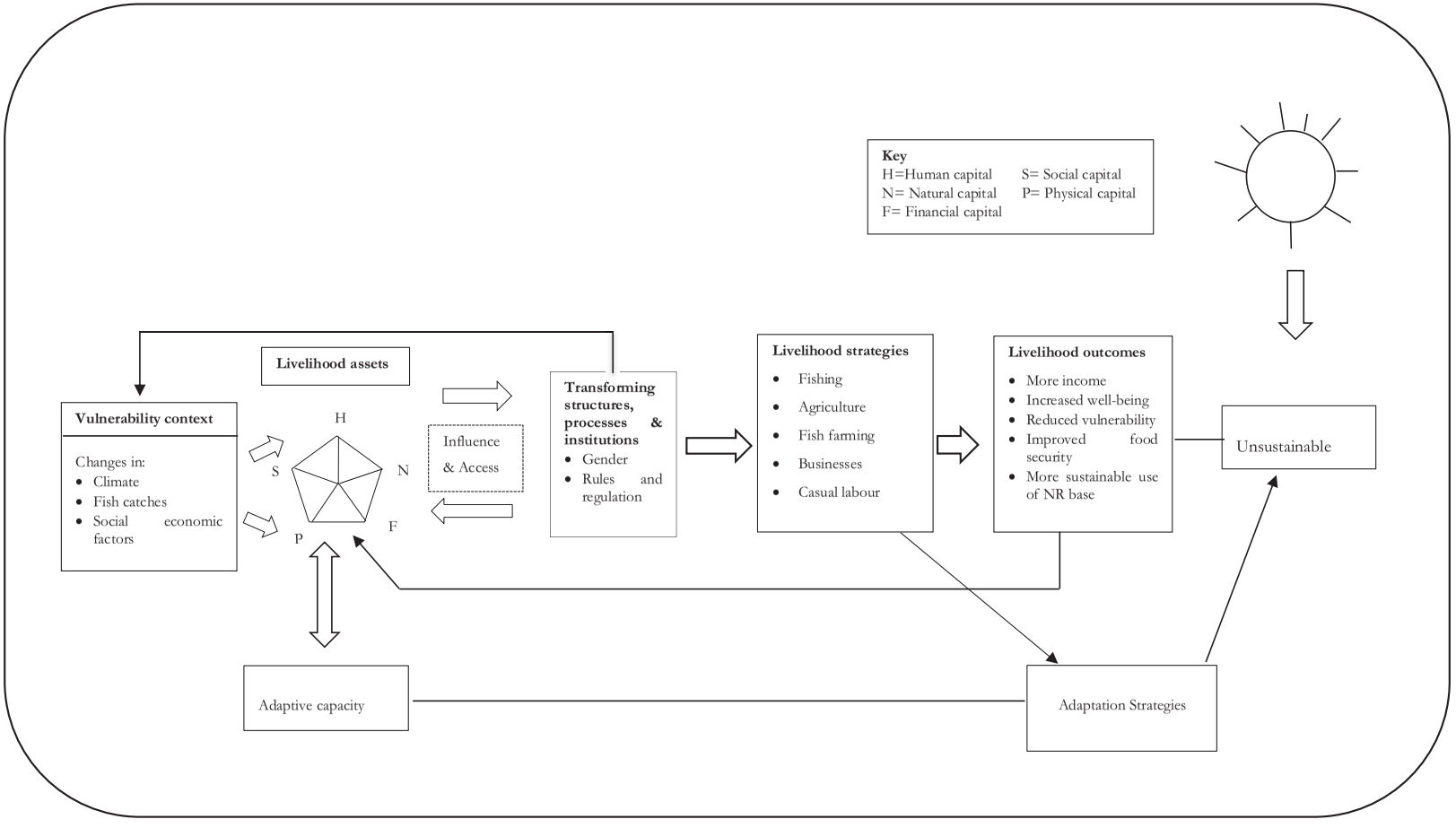

Figure 2: Sustainable livelihood Framework. Adapted from Carney (1998) and Scoones (1998).

vulnerability (Kelly & Adger 2000; Füssel 2007; Parry *et al.* 2007) which could be qualitative, quantitative, or integrated (Islam *et al.* 2014; Brugère 2015; Colburn *et al.* 2016).

In this thesis, I followed the end point approach in assessing vulnerability. This follows the conceptual framework prescribed by the Intergovernmental Panel on Climate Change (IPCC). In this case, vulnerability context was assessed qualitatively. The IPCC framework focuses on exposure, sensitivity, and adaptive capacity (McCarthy *et al.* 2001; Parry *et al.* 2007). These three concepts are interrelated as well as spatially and temporally context-specific (Smit *et al.* 2000; Smit & Pilifosova 2003; Smith *et al.* 2003; Smit & Wandel, 2006).

This thesis analyzed the vulnerability context at household level using assets which they possess as the analysis unit. Even at this fine-scale unit of analysis, differences within the household could not be considered. However, this was considered the only challenge associated with the household concept (Quisumbing 2003). The first sub component of vulnerability is exposure, which is associated with stressors the different assets were subjected to, in respect to this thesis, these stressors are related to extreme weather events due to global environmental changes. The second component of vulnerability, sensitivity, is the extent to which a system will respond to any changes. In this case, sensitivity was associated with changes in the number of fishers, fish catches, agricultural produce, and fishing distance. The third component of vulnerability is adaptive capacity and is defined as the ability to adjust to stressors. This adaptation could be planned or spontaneous (Downing *et al.* 2001). Adaptive capacity was furthermore conceptualized as a function of the five asset types and was determined quantitatively using household characteristics as proxy indicators (Gbetibouo & Ringler 2009; Nelson *et al.* 2010). For example, family size, education level, and age were used as proxy indicators to determine human capital. In this case, it also helped to assess the impact of development initiatives in reducing vulnerability in the study area.

While this research was limited to only climatic factors and their impact on different assets, households could also be vulnerable to other non-climate factors such as poverty, inequality, food insecurity, conflict, disease, and globalization that also affect the exposure, sensitivity and adaptive capacity of systems and communities (Adger *et al.* 2007).

This research further extended the adaptation concept by looking at sustainable adaptation which is defined as "a set of actions that contribute to socially and environmentally sustainable development pathways that include social justice and environmental integrity" (Eriksen *et al.* 2011). This concept acknowledges that not all adaptations are good. For example, the adjustment of fishing gears in response to low fish catches could be an unsustainable strategy because immature fish will be caught. Sustainable adaptation has four principles that inform how the research is conducted. These principles include: a. identifying the vulnerability context; b. outcome of drivers of adaptation processes which included differences in values and interests; c. local knowledge identified through perceptions as an important aspect of adaptation process and; d. relationships between local and global potential feedback needed to be well thought of (Eriksen *et al.* 2011).

In describing vulnerability context, the communities' perceptions and local knowledge are key linkages in which they cite changes in their assets (Cote & Nightingale 2012; Gufu 2014; Gaspare *et al.* 2015; Donda & Manyungwa-Pasani 2018). Perceptions are associated with psychology, which is the science and behaviour of the mind (Eagly & Chaiken 1993). In this study perceptions were conceptualized through looking at the experience of the Lake Malawi fishing communities with global environmental and asset changes. This experience is a function of the memory to recollect previous events which serve as a point of reference to the current state of assets. This process defines how a household views their status and is iterated with memory recollections. These processes give rise to expected changes in behaviour, which could either lead to remaining in the status quo or adapting (Ingold 2000). The perceptions framework has been used to situate global environmental change studies in Tanzania (Ogalleh *et al.* 2012) and Malawi (Kalanda-Joshua *et al.* 2011; Simelton *et al.* 2013; Nkomwa *et al.* 2014). This form of knowledge generated through perceptions could be misleading and care should be taken to validate it (Broadhead & Howard 2011). In this research perceptions were validated by using conventional scientific knowledge.

5.2 Transforming structure and processes

Livelihood assets are not only affected by the vulnerability context, but also by structures, processes, and institutions which influence their access. There are many different processes and structures but in this thesis only gender was considered due to its importance in influencing livelihood strategies in a matrilineal kinship dominated area (Phiri 1983; Nyanga *et al.* 2012; Thorpe *et al.* 2014; Samndong &

Kjosavik 2017). Furthermore, the SLF has also been used to contextualize gender and livelihoods in fisheries (Holvoet 2008).

Gender is a social institution, which interacts with class, ethnicity and other factors shaping processes of ecological change (Peet & Hartwick 2015). Women bear the cost of gender inequalities, which are distributed widely and could be a cause of persistent poverty for all members of the society (Laukkonen *et al.* 2009). In Malawi fishing communities, gender identity is an important attribute which affects power relations. Among other factors, gender has a bearing on the fishing communities' social complexities and heterogeneity (Haraldsdottir 2002). Furthermore, both men and women are part of the problem of low fish catches due to their differences. If sustainable resource management and community well-being are to be maintained, both males and females must be mobilized together. However, policies and interventions for development in fisheries fail to deal with the complexity of gender issues (Harrison 1995). Therefore, inclusion of women in fisheries goes beyond fisheries resources management, additionally fostering livelihood access and outcomes (Gätke 2008).

Analysis of gender relations and women's experiences are used to inform all social research (Porter 2014). This thesis used the Gender and Development (GAD) theory to explore the research questions focused on gender relations and power distribution (Razavi & Miller 1995). The theory helped to situate women and men in the fish value chain with regards to changes in livelihood strategies based on gender division of labour for their productive roles. GAD allowed the research to answer questions regarding the drivers of coping with changes related to climate and fish catches, which could differ based on sex (Thorpe *et al.* 2014). This also improved the understanding of the livelihood profiles because gender was also viewed as a social identity (Haraldsdottir 2002). This thesis also looked beyond women as processors and men as fishers (Holvoet 2008). However, the challenges with GAD is that it does not look beyond an individual's sex, unlike another feminist theory called intersectionality. This theory operationalizes gender as an intersection between sex, power and class (Shields 2008).

5.3 Livelihood outcomes

Having a livelihood is not enough, if the processes of acquiring such resources is not sustainable. In assessing the livelihood outcomes, a sustainable food systems approach was used. The approach also looked at the vulnerability context of assets which include global environmental change, and other

shocks such as socio-economic changes while it hypothesizes food and nutrition security as its outcome (Allen & Prosperi 2016).

The food system takes its roots from sustainable agriculture production and trade - offs along the value chain. Using the food systems to understand the vulnerability context of Lake Malawi's fishing community will not only help examine how strategies are achieved, but also how future generations might be affected by the present behavior. Such current behaviour might include unsustainable fishing and farming practices. Therefore, a sustainable food system is defined as *"one that provides health food to meet current food needs while maintain healthy ecosystems that can also provide food for generations to come, with minimal negative impact to the environment; encourages local production and distribution infrastructures; makes nutritious food available, accessible and affordable to all; is humane and just, protecting farmers and other workers, consumer, and communities"* (Story *et al.* 2009).

Sustainable Food Systems (SFS) are multidimensional and complex. Its linking elements include sustainable development, a concept that stems from the Agenda 21 of the Rio conference on sustainable development as reflected in the Brundtland Report (Brundtland 1987). In this thesis, SFS is concerned with activities which fishing communities are currently doing that have a bearing on future generations. The other component of the SFS is the food system, which is composed of all activities within the food value chain from production to consumption, and also goes further to look at food disposal (Ericksen 2008). The interactions of these elements are important in curbing such issues where climate related changes could be accelerated in the process of food production. The final output of a food system is food security (Allen & Prosperi 2016).

Food security is also another multidimensional concept. For one to be food secure, food must be available at all times, and can be accessed with ease to meet dietary needs (FAO 1996). Food security is a function of availability, access, and utilization. However, over time the concept has been expanded to include stability (Haug 2018), which was not considered in this study. This concept cut across the four interlinked studies in this thesis. Despite the challenges in finding indicators to suit different contexts as outlined in the good and bad news narratives (ibid), this research was shaped by the good news narratives especially considering "climate change is going to negatively affect food production and poverty, therefore adaptation to climate change is urgently needed" (Haug 2018).

Despite food security being the preferred outcome of any food system, it further interacts with social and environmental welfare. Under social welfare, elements such as income, employment, social capital, and human capital interact. These are in essence part of our livelihood assets. On the other hand, environmental welfare concerns itself with aspects of ecosystems services from natural capital, and ecosystem stocks and flows (Ingram 2011).

6. METHODOLOGY

6.1 Study area

Theory and concepts shape how knowledge is produced and how research ought to be conducted. The research studies were conducted in Nkhotakota district in Malawi. Nkhotakota is located on the western shore of Lake Malawi. The district is one of the five-lakeshore districts on the Malawi side of the lake (Figure 1). Nkhotakota is located in the central administrative region of Malawi together with eight other districts. Amongst the eight districts in this region, Nkhotakota is the least populated (303, 659) with the exception of the Ntchisi district (224, 098). Additionally, the gender parity within Nkhotakota district is almost equal (GoM 2008).

Historically Nkhotakota and other lakeshore districts of Malawi were slave trading hubs, where Arabs could ship slaves to Zanzibar in Tanzania. Because of this many locals on the shores of Lake Malawi were converted to Islam. Slave trading caused Anglican missionaries to settle in Nkhotakota and end such practices (Phiri 1983). Christian and Islamic influences promoted male household heads even in areas where matrilineal households were predominant such as Nkhotakota (Haraldsdottir 2002). As of Malawi's 2008 population census, Christians (73%) dominated the district compared to Muslims and other religious groups (GoM 2008).

Furthermore, the people of Nkhotakota are from Chewa tribe with the exception of areas in the Northern part of the district where people are from Tonga tribe (attributed to proximity to Nkhatabay where Tonga dominates). Other tribes have also immigrated to Nkhotakota due to their need to survive through fishing. Due to such migrations, there have been intermarriages between tribes. This has also greatly impacted Nkhotakota's dominant matrilineal kinships on control of capital assets such as land. The people of Nkhotakota have diversified livelihoods strategies (GoM 2010; Phiri 1983).

The livelihood strategies of Nkhotakota people revolve around fishing, agriculture, and businesses related activities. Businesses are centered on fish and agriculture, but also consist of small retail shops. Despite fishing being a major livelihood source, only 1% of Nkhotakota's population owns fishing gear (GoM 2008; GoM 2015a). This could be attributed to the cost needed to invest in the equipment (Simtowe 2010). In other areas like Lake Malombe, south of Lake Malawi, fishing crew who do not own fishing equipment have more power than the gear owners in controlling where and when to fish

and how proceeds from fish sales are shared (Hara & Jul-Larsen 2003). This too could be the case with Nkhotakota, and is reported in many other fishing communities along Lake Malawi (Haraldsdottir 2002). On the other hand, fishing gear ownership by women in Nkhotakota represents a small proportion (2%) of the total gears in the district (GoM 2015a). These numbers only represent active fishers who are permanent residents in the district. Even though Nkhotakota fish catches have been fluctuating, fishers use multiple fishing gears to catch many fish species (Sipawe *et al.* 2001). This has an impact on the availability and access to food. Furthermore, extreme weather events have been exerting pressure on the natural resources on which the people of Nkhotakota base their livelihoods. For instance in April 2018, Nkhotakota was hit by flash floods, which destroyed crops, human lives, and property (Mwanza 2018). In addition to fishing, many households are also involved in other fish value chain activities and farming.

Despite farming being another livelihood strategy, most of the households do not possess large sizes of land holdings. The majority of land is owned by sugar cane estates and the remaining parts are reserved for forest and wildlife (Table 2). The remaining land has steep topography, which makes it rough and impossible to farm (GoM 2010).

Table 2: Proportion of land distribution in Nkhotakota

Area	Hectare	Proportion (%)
Game Reserve	108, 200	7.0
Forest Reserve	36, 600	2.4
Land for subsistence farming	99, 862	6.5
Sugar Estates	800, 000	51.8
Other Estates	500, 000	32.4
Total	**1,544,462**	**100**

Source: (GoM 2010).

Vulnerabilities related to extreme weather events informed the selection of the research area by the funders of this research, the Capacity Building for Managing Climate Change Programme in Malawi (CABMACC). This programme was financed by the Norwegian Ministry of Foreign Affairs (MFA) and was implemented in Malawi's climate hotspots which includes Nkhotakota (CABMACC 2013).

The sites for the interlinked studies which formed the basis of this thesis were concentrated within 1 km from Lake Malawi's shoreline, except for the fish farming study where respondent sampling was

extended to 30 km from the shoreline. Despite Nkhotakota having six Traditional Authorities (TAs)[1], the research did not consider Kafuzila households in the sampling framework. This was attributed to challenges in accessing the fishing villages during data collection which coincided with the rainy season. The selection of the other TAs was informed by the exploratory surveys and participant observations conducted prior to data collection.

The research sites were between the Global Positioning System (GPS) coordinates of 12°26'40.8"S 34°10'38.4"E and 13°21'34.8"S 34°17'54.3"E. These two demarcations were the extreme ends with Dwangwa in Traditional Authority Kanyenda in the northern part and Mtosa in the southern in TA Mwadzama (Figure 3). This allowed the research to accommodate for possible diversity between the fishing communities. The majority of household members were permanent residents; however, a minority were migrant fishers and fish traders. The migrant fishers were attempting to gain livelihoods through fishing even though the fish catch composition in Nkhotakota had changed (Sipawe *et al.* 2001). Migrants were concentrated closer to the lake compared to the uplands where most of the fish farming is conducted. The research sites were organized in villages headed by chiefs. Villages varied in terms of size in area, family sizes, housing units and other social amenities. However, households within a village were closely related. Common housing units were made from mud and grass thatched. However, a small proportion had corrugated iron sheets and the housing structures were made from either unburnt or burnt bricks. Few houses had electricity from the power grip but instead used solar units to generate energy.

6.2 Philosophical standpoints

It is important to make philosophical standpoints known to understand the research context. These standpoints influence the nature of the research, support what is real, define how knowledge is produced, and deal with conflicts between research outcomes (Crotty 1998; Moon & Blackman 2014). In this research, I explored how fisheries systems could be impacted by extreme weather events. This knowledge was the focal point of this research, while acknowledging that Malawi's agro based economy and fisheries, which are among main livelihood sources, are being affected by continued low productivity. Therefore, with the increased frequency of extreme weather events over the last decade, finding sustainable solutions to enhance livelihoods for the majority poor people is essential.

[1] Traditional Authority (TA) is a subdivision of a district and is ruled by a chief. Under a TA there are several village chiefs who report to the TA and a village is the smallest administrative unit.

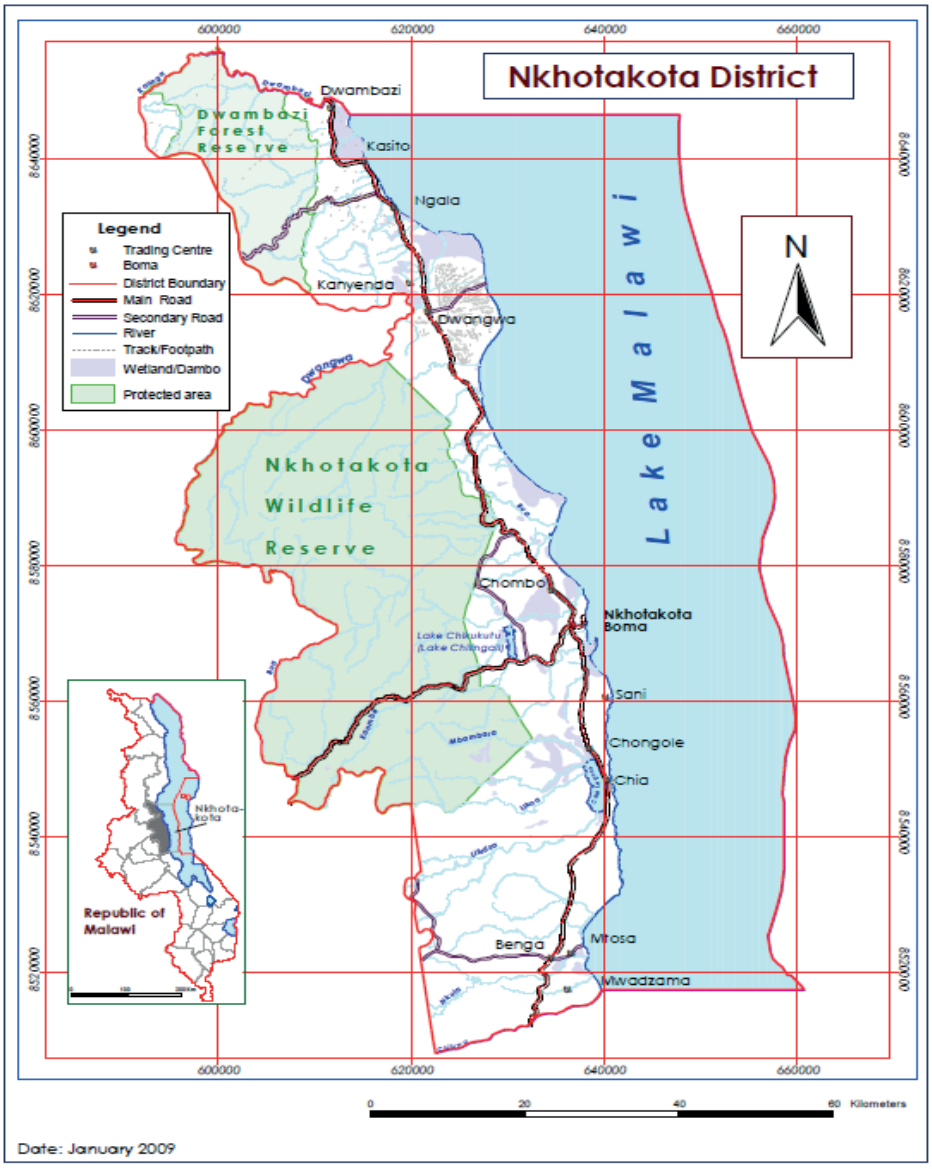

Figure 3: Map showing Nkhotakota District. Source: (GoM 2010).

This research therefore sees the world's existence as independent of human experiences. Meaning that reality does not vary based on a person's experience (Crotty 1998; Evely *et al.* 2008; Bhaskar 2014).

This position leans on the *critical realist philosophy*, which states that, "Reality is an interplay between a concrete structure and influenced by perceptions" (Evely *et al.* 2008). This ontological position is suitable for livelihoods research which requires an interdisciplinary approach to cut through the interaction of social and natural sciences (Prowse 2010).

Furthermore, in this research, knowledge was produced following *constructionism epistemology*. Under this viewpoint, the subject's reality is a product of the interplay between the subject and the object (Crotty 1998). Therefore, individuals will define similar events in different ways. For this research, this reality could be how households perceive the climate status and fish catches within an area. This type of epistemology enhances context specific solutions to conservation challenges (Waylen *et al.* 2010). Constructionism epistemology has also been used to study risk perceptions of global environmental changes such as floods (ibid). This previous use of constructionism epistemology justifies using the approach to assesses fishers' perceptions on changes related to climate and fish catches.

Therefore, to respond to the objectives of this research, I used interdisciplinary approaches and tried different methods to understand livelihoods and challenges of lakeshore communities (Bammer 2005). Therefore, the research employed *pragmatic philosophical perspectives*, which are not tied to one system of philosophy or reality, but dwells on problems (Creswell 2014). It uses many methods to derive knowledge on the problems identified and focuses on what provides solutions (Patton 1990; Cherryholmes 1992; Morgan 2007; Creswell 2014). This perspective enabled this research to use mixed methods approaches (qualitative and quantitative) (Teddlie & Yu 2007). Such diverse approaches have been advocated for in livelihoods research due the need to touch upon several aspects of people's lives (Murray 2000).

There is an increased need for interdisciplinary research in fisheries as inclusive policies need to show a holistic approach. However, the speed of knowledge generation using these approaches has been slow (Phillipson & Symes 2013). Different areas of knowledge production have been working independently, causing many policies to be misinformed. Interdisciplinary work is a well-placed paradigm due to fisheries being complex in nature. At the same time, sustainable fisheries management needs to be placed in a broad framework. This approach also advocates for decentralized systems that acknowledge the importance of drawing upon knowledge of the resource users. However, at a global

level, fisheries social sciences have been partially or seldomly utilized due to one-sided quantitatively informed policies through stock assessment (Phillipson & Symes 2013).

6.3 Research design and data collection

The research was designed to respond and offer solutions to Lake Malawi's fishing communities using interdisciplinary approaches. The four interlinked studies were designed specifically for that purpose to look at: a. perceptions of fishers on climate change and coping strategies; b. gendered perspectives on fish value chain under perceived climate change; c. fish farming as an alternative livelihood for Lake Malawi communities under environment changes; and d. the impact of development initiatives in building adaptive capacity of Lake Malawi's fishing communities.

6.4 Data collection preparations

Before data collection, exploratory surveys and field observations were conducted. These were meant to contextualize the area in which the research was to be conducted. Otherwise, without such exercises the research could be expensive, with higher chances of collecting data not related to research questions. This phase was also used to obtain consent from the regulatory bodies to conduct the research. Furthermore, this phase enabled the researcher to observe and contextualize the research, because vulnerability of communities varies according to geographical space and time (Smith *et al.* 2003). These communities are also not homogenous, therefore their context had to be mapped (Cleaver 1999). At the end of the phase, research tools such as semi – structured questionnaires for household surveys (Appendix), check lists for Focus Group Discussions (FDGs) and Key Informant Interviews (KIIs) were developed. These tools were pretested to: gauge the flow of the questions, remove redundancies, and check the timing and the meaning of similar questions across different respondents (Bryman 2012).

6.5 Primary data collection

In order to administer the research study tools, different approaches were used to select the respondents. The four interlinked studies adopted the concept of the household as a unit of measure. A household was defined as a group of people that share productive assets and food, living under the same roof and contributing towards their livelihoods (Mvula 2002). An emphasis was put on trying to understand the households in their local perspectives. In the household surveys, the research mostly focused on household heads as representatives of the families. For the first two studies a. fishers' perceptions and coping strategies and b. gendered perspectives on fish value chain, sampling of the

households was done in three stages. The first stage involved stratified sampling of accessible fishing landing sites within the district. The second stage involved random sampling of villages within these accessible sites and in the third stage, another random sampling was done to select households who were actively involved in the fish value chain through ownership of fishing gears, vessels, or both.

For the third study on fishing farming as an alternative livelihood source, a list of fish farmers was solicited from Nkhotakota District Fisheries Office. This list was obtained to indicate farmers to include in the sample. However, during the exploratory surveys, we observed that many of those on the list were just potential farmers without fishponds. These households had registered their names as potential beneficiaries of the Local Development Fund (LDF)[2] aimed to assist them to venture into fish farming. Therefore, we instead randomly sampled households who only owned fishponds. The sample size for this study is 47. Although the sample size seems small in respect to the district population, it is a good representation of the households that owned fishponds.

In the final study on development initiatives, livelihood assets and adaptive capacity among Lake Malawi fishing communities, we used a two – stage sampling. The first stage involved stratified sampling of accessible villages within 1 km from Lake Malawi's shoreline. The second stage involved random sampling of households from the selected villages. Selection of households from these villages was informed by their population proportion to that of the total district (Levy & Lemeshow 1999). However, this study was not restricted in who the respondents were, unlike the other three studies where only households who owned either fishing equipment or fishponds were considered.

The sampling methods for selecting respondents in the four studies provided equal opportunity for all households within the study sites to participate in the research. Therefore, no biases were expected, as sampling was representative.

Table 3 summarizes the periods in which the research data was collected, sample sizes for household surveys, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) per study. The household survey sample sizes ranged from 47 to 399 respondents, whereas the focus group

[2] LDF is a Malawi government initiative designed to pool together all funding for local development initiatives into one basket to realize a harmonized approach in their implementation to achieve efficiency.

discussions (FGDs) and key informant interviews (KIIs) ranged from 5 to 15 and 5 to 10 per study, respectively.

Table 3: Data collection periods and sample sizes for different methods per study.

Study	Phase 1	Phase 2	Household survey	FGDs	KIIs
I	Aug – Dec 2015	Feb - April 2016	112	10	5
II	Jan - June 2016	June - July 2017	113	5	5
III	Jan – May 2016	July 2017	47	10	5
IV	Aug – Dec 2015	June - Aug 2017	399	15	10
Total			**671**	**40**	**25**

NB: FGDs is Focus Group Discussions and KIIs is Key Informant Interviews

Focus group discussions were conducted as a follow up to key issues that emanated during the participants observation, exploratory and household surveys. These processes were iterative in nature and were conducted until saturation was reached. In forming FDGs, certain criteria was considered to get diversified opinions. Some of the traits included age, gender, and role in the area. Care was also taken in combined gender groups to ensure women's voices were not suppressed by dominant males. A similar process was used for the KIIs, except that it only targeted respondents based on their role within the community. The KIIs comprised of a diverse group of stakeholders. Both the FGDs and KIIs helped to answer questions related to how and why. Furthermore, these two methods (FGDs and KIIs) allows the researcher to gather a lot of data within a very short period of time (Stewart & Shamdasani 2014).

6.6 Secondary data collection

In addition to primary data, this research also used secondary data. For the analysis of climate trends for the area (1982 – 2016), the number of rainy days, temperature, and precipitation (daily, monthly, and annual) were all secondary data. The data was accessed from Dwangwa Weather Station. Additionally, the research used secondary data on annual fish catch statistics (2000 – 2013) from Malawi Annual Economic Report (GoM 2014). The fish catches statistics and climate data were used to validate the perceptions of the fishing communities on fish catch trends in respect to perceived exposure to extreme weather events.

In order to understand the extent in which climate change has been researched in Malawi, various other secondary data sources were used. These included archival documents, journal articles, national reports, policy documents, conference proceedings and official statistics. Other secondary data was related to different development initiatives implemented in the study area. Hard copies of project documents were analysed while supplementary project information was accessed from the internet.

6.7 Data Analysis

The research used multiple analytical methods to analyse primary and secondary data. Thematic analysis was used to analyse all qualitative data from the 40 focus group discussion and 25 key informant interviews (Braun & Clarke 2006). The qualitative material was transcribed and sorted based on the information source. The data was converted into short notes for easier coding and categorization of concepts. Policy documents, reports, and archival documents were analysed using an iterative exploratory process in which key information was extracted (White & Marsh 2006; Thai *et al.* 2008). The research also validated the qualitative material through ensuring that the interpretation of the data and the participants' meanings were the same (Maxwell 2013). This was done by continuously cross checking with the respondents to ensure what we captured was a true reflection of their meaning.

Various quantitative analytical methods were used to analyse household survey data and other data collected from secondary sources such as climate and fish catches. Table 4 shows different quantitative (descriptive and inferential) methods used in the various studies. Descriptive statistics were calculated to show the distribution of various household characteristics and the results were reported as such. For inferential methods, most of the methods assumed a normal distribution. The inferential methods used various significant levels as a safeguard to committing Type 1 error, which is defined as "incorrectly rejecting the null hypothesis or rejecting a null hypothesis that is actually true" (Healey 2014). The levels of significance ranged from 0.01 to 0.1. These levels correspond to a level of certainty in which the results are closer to the truth. The computer software used to analyse both descriptive and inferential statistics were IBM SPSS Statistics 24 (IBM 2016) and Stata version 14.2 (StataCorp 2015).

Table 4: Data analytical methods used in various articles.

Study	Qualitative	Quantitative	
		Descriptive statistics	**Inferential Statistics**
I	• Thematic analysis	• Mean • Range • Frequency • Proportion	• Cross tabulations • Pearson's correlation coefficient • Binary logistic regression • Ordinary Least Square regression (OLS) • Mann-Kendall (MK) tests
II	• Thematic analysis	• Mean • Range • Frequency • Proportion	• Cross tabulations • Independent sample t-test
III	• Thematic analysis	• Mean • Range • Frequency • Proportion	• Paired - Samples t – tests • Pearson's correlation coefficient • Spearman's correlation coefficient
IV	• None	• Mean • Range • Frequency • Proportion	• Cross tabulations • Independent sample t-test • Gini coefficient • Principal Component Analysis

The multiple methods used in this thesis have also been linked to research objectives and key concepts (Table 5). This table also shows that the thesis took a mixed methods approach, with some of the methods and concepts interlinking between the research objectives.

6.8 Validity and reliability

Combining different methods of data collection and analysis in each study (Tables 4 & 5) improved strength of the inquiry process, credibility of the research results, and validity (Bryman 2012; Creswell 2014). Validity is associated with credibility and is a process that reveals accuracy of the extent to which research conclusions corresponds with reality (McBurney & White 2007). For quantitative research, this assures the possibility of replication. That is to say, within a certain limit of experimental error or random error, if the same methods are used with the same sample, the results should be the same (Cohen *et al.* 2008). Qualitative research is based on determination of whether the findings are accurate from the standpoint of the researcher, the participant, or the reader of an account (Creswell & Miller 2000). In this research, multiple strategies were used in achieving highest validity. Threats to validity were also minimized through clarity in the research problem, use of appropriate research design, selection of a representative and unbiased sample, use of valid and reliable instruments for data collection, and application of appropriate analytical tools (Oluwatayo 2012).

Table 5: Linking research objectives to the theory and data capturing methods

Research objectives	Key concepts	Methods
RO1. To explore the effects of perceived climate change on Lake Malawi's small scale fishers and the determinants to their coping strategies	Vulnerability Perceptions	Exploratory surveys Field observations Household interviews Focus Group Discussions Key Informant Interviews Policy document analysis
RO2. To examine gender roles on fish value chain, livelihoods patterns and coping strategies for Lake Malawi's small scale fishers under the influence of climate related change.	Vulnerability Gender and Development Perceptions	Exploratory surveys Field observations Participant observation Household interviews Focus Group Discussion Key Informant Interviews Policy document analysis
RO3. To examine the status of fish farming and its feasibility as a livelihood strategy to Lake Malawi's smal lscale fishers	Sustainable food systems	Exploratory surveys Field observations Household interviews Focus Group Discussion Key Informant Interviews Policy document analysis
RO4. To explore development initiatives, livelihood assets and adaptive capacity among Lake Malawi fishing communities.	Adaptive capacity Sustainable livelihoods approach	Exploratory surveys Field observations Participant observation Household interviews Focus Group Discussion Key Informant Interviews Projects document analysis

The following steps were done to enhance the researcher's ability to assess the accuracy of the findings as well as convince readers of that accuracy:

a. Triangulation of different data sources of information through examining evidence from various sources.

b. Clarification of biases associated with the participation of the researcher shared in the study. This created open and honest narratives that resonate well with readers.

c. More time was spent in the field to develop an in-depth understanding of the conditions under which the research was conducted. This helps the researcher convey details about the sites and the people that lends credibility to the narrative accounts.

6.9 Ethical Considerations

Despite the need to uphold high validity and reliability, social research has challenges associated with quality of the knowledge produced. In most cases, it is a function of power asymmetry between the respondents and the interviewer (researcher). If there is no trust, then getting good data will be a

problem. Therefore, research ethics has to be considered at every stage in the research cycle (Brinkmann & Kvale 2015). In this research, ethical considerations were built into all stages of the research. For instance at the thematizing stage, the studies were framed so that their purpose leads to improvement of the fishing communities' livelihoods.

Before data collection, permission was granted by the District Assembly and various village chiefs to conduct research in their areas. Collaborating with Nkhotakota district fisheries office facilitated these processes. When requesting permission, the objectives and purposes of research were communicated to the subjects as academic but important to influence policy formulation. The other informed consent was solicited during household survey interviews, FGDs and KIIs. Getting consent is very important as it builds confidence in the respondents and emphasizes on not harming the respondents or getting data under false pretenses and assures confidentiality of the research subjects (Brinkmann & Kvale 2015). The results of the research identifies the respondents through using pseudonyms as a means of protecting them. This was also applied to the names of places (Lankshear & Knobel 2004). As researchers, our integrity was upheld highly because the interviews were the main method in which knowledge was produced apart from the analysis of secondary data sources and field observations.

6.10 Limitations of the research

Despite processes of ensuring quality and credible outcomes, the research had the following limitations:

a. Failure to access quality historical data from closer weather stations on climate to enable map bio-spherical loop. This might affect the correlation of the fishers' perceptions to the climate data gathered at Dwangwa Weather Station.

b. Similarly, we failed to access time series fish stock estimates for Nkhotakota. We instead used secondary data from the Malawi Annual Economic Report.

c. Heavy rains and flooding prevented the researcher from visiting others areas during the exploratory survey phase.

7. SUMMARY OF PAPERS

This section presents a summary of the four interlinked studies which are a basis of this thesis. The section also reveals the relationships between the findings from these studies. The concepts and theories employed in the four different studies are articulated fully in chapter 5 of this thesis, therefore in this chapter I will just mention them.

7.1 Paper I: Evaluation of small-scale fishers' perceptions on climate change and their coping strategies: Insights from Lake Malawi

The rationale of this article was to start off by evaluating the perceived effects of climate change on Lake Malawi's small scale fishers. The paper also articulates how the fishers cope with the climate change induced changes on fish catches and the drivers affecting their coping strategies. The research study was situated within the vulnerability and perception conceptual frameworks. As such, mixed methods of inquiry were used to generate knowledge.

The paper revealed that fishing was a common livelihood and the majority of the fishers were fishing in the offshore waters. Boats with engines were less common than dugout canoes and other plank boats. Gillnets were the most common fishing gear over seine nets and traps. With such a multi gear fishery, the study also revealed multiple fish species caught in the study area including: *Copadichromis virginalis, Bagrus meridionalis, Mylochromis guentheri, Rhamphochromis spp., Synodontis njassae, Tramitichromis intermedius, Opsaridium microcephalum, Oreochromis species* and *Engraulicypris sardella.*

The study also showed that extreme weather events experienced in the study area revolved around rainfall and temperature. The specific exposures included increased drought frequencies, erratic rainfall, floods, dry spells, and southern easterly winds locally known as *mwera*. These exposures affected the livelihoods of the communities along Lake Malawi. The research further illustrated disparities between fishers' perceptions of climate change and conventional scientific knowledge (34 years (1982 – 2016)) on climate. Despite fishers citing changes in climate, the meteorological analysis for temperature and precipitation trends was not significant. This is consistent with other fisheries studies where the local knowledge of the fishers could not match the conventional scientific knowledge on the temporal and spatial changes in their ecosystem (Gaspare *et al.* 2015). Despite the changes experienced by fishers not warranting a significant change categorization, the average age of

respondents (36 to 46 years), was a good indicator to support the fishers' perceptions based on their experience (Nsiku 2001). The low fish catches and changes in fish species and size composition was also evident due to the absence of large fish, signaling ecosystem changes. Small sized fish like *Engraulicypris sardella* and *Copadichromis virginalis* dominated fish catches compared to larger fish species in the past. Additionally, evidence of illegal fishing gears and fishing in restricted locations were prevalent. Therefore, attributing changes in fish catches entirely to changes in climate could not be warranted, even though climate has been known to affect the fisheries ecosystem (Cheung *et al.* 2009). From this article, it was difficult to conclude whether climate was impacting the fishery. These findings also corroborated with Brugère (2015), in the summary of six global case studies commissioned by FAO on quantifying vulnerability of fisheries to global environmental changes. In those studies the author failed to attribute fish population changes to either climate change or overfishing.

Insights on how fishers adjust to such changes brings in new knowledge that is essential to guide evidence based policy formulation and implementation, which could strengthen adaptive and ecosystems fisheries management (Walters 1986; Nsiku 2001). The article also revealed many coping strategies were implemented. These included an increase in fishing hours, increase in fishing distances, and increased fishing efficiency by reducing fishing gear mesh sizes, expansion of agricultural land, venturing in petty business activities, and providing labour services to agriculture and fisheries. With such diverse activities, the study argues for a flexible policy approach that balances social and ecological aspects. These coping strategies were influenced by age, marital status, education, and annual income. However, these coping strategies might pose challenges in balancing sustainable fisheries exploitation and livelihoods. Alternatively, though the study revealed lack of capacity to fish in the offshore waters, research indicates an abundance of untapped fish stocks (Thompson & Allison 1997).

The paper also strengthened the need for multi sectoral planning in fisheries, as both ecological and social factors could be responsible for the changes experienced. In conclusion, this paper contributes to methods and a modified conceptual framework for situating vulnerable small scale fishers with the use of local knowledge of the ecosystem. Currently not many fisheries related studies have combined natural and social sciences to understand how small scale fishers of Lake Malawi are impacted by extreme weather events. However, further studies might need to consider hydro-biological modelling between fish catches and climate data for many other sites along Lake Malawi.

7.2 Paper II: A gendered perspective on fish value chain, livelihoods patterns and coping strategies under perceived climate change - Insights from Malawi smallscale fishers

Paper 2 illustrates that gender is an important social factor that must be considered in decision making for enhancing small scale fishers' livelihoods under the influence of climate related changes. In paper 1, the fishers' vulnerability to the perceived changes exposed a gender knowledge gap on how climate change was affecting households involved in the fisheries value chain. The Gender and Development (GAD) theory and Harvard Analytical framework for gender roles were used to situate this article. Furthermore, elements of the IPCC vulnerability framework helped understand the households' vulnerability context.

This paper shows that women and men viewed their exposure to climate identically, while their views on fish catches differed. Differences in views were also observed for the general environmental outlook, number of trees, and dominant fish species in the study area. However, women's participation and their roles in the fisheries value chain have improved from their dominant post harvesting roles. The increased participation for women were in the areas of pre-catching activities and ownership of fishing gears. However, such improvements were not attributed to the changes perceived in climate and fish catches but to having purchasing power to invest in fishing equipment and through economic empowerment by NGOs. Such changes did not result in women having power to control the proceeds from fisheries related activities but did improve their households' socioeconomic status and active participation in fisheries management structures. The implication of women's increased participation in fisheries activities also exposed them to transactional sex with the fishers. However, females not having power and control of resources was enshrined in masculinity dominance despite the study area being matrilineal dominant. This observation was attributed mainly to intermarriages with migrant fishers who were from patrilineal background.

This paper shows that livelihoods sources over the last 20 years (1996-2016) differed greatly between women and men. The differences and changes in livelihoods were driven by climate among other factors. The climatic factors had an effect on agricultural yields and made households seek alternative livelihood strategies. Despite the reduced reliance on agriculture as a main livelihood source for the respondents as compared to 20 years ago, the households have started returning to agriculture. The cyclic pattern was attributed to fluctuating fish catches and the need to survive. This clearly shows that fisheries offer an easy livelihood source attributed to its open accessibility. Flexible movement is

important in enhancing sustainable livelihoods for community-managed natural resources, but caution needs to be taken as it also promotes opportunistic behaviour (Allison & Mvula 2002). Furthermore, coping strategies between women and men differed. Women tended to use business related strategies compared to men who were involved in agriculture production and fish catching but could also migrate to other fishing grounds and even participate in offshore fishing. Women also used group mechanisms like Village Savings Loans (VSLs), as safety nets while most men employed individual level strategies.

The use of multiple research methods in this paper provided a platform to inform policies on natural resources and gender. The paper has also provided new evidence on the role of women on fluctuating fisheries resources. The study also reveals that even in predominant matrilineal kinship communities, masculinity dominance and gender stereotypes still exist. This study also informs the implementation of the new Malawi National Fisheries and Aquaculture Policy (GoM 2016), which spells out the importance of gender in advancing sustainable livelihoods but has no strategies to achieve it.

The theory employed in this paper had limitations in its explanatory power as it only looked at gender roles. Although the paper explored how and why questions through the FGDs and KIIs, it under theorized the study. Therefore, the intersectionality theory would have been a better choice as it looks beyond gender roles (Shields 2008). Furthermore, assessing intra-household vulnerability of the key players in the fisheries value chain could strengthen the adaptation processes.

7.3 Paper III: Is fish farming an illusion for Lake Malawi riparian communities under environmental changes?

This paper is an extension of papers 1 and 2, where the need to assess other potential coping strategies for communities along Lake Malawi was conducted. In papers 1 and 2, fishers were found to move between fisheries and agriculture. These strategies are also at risk due to increased incidences of extreme weather events. In addition, other coping strategies in fisheries could lead to unsustainable exploitation of the fishery. Therefore, paper 3 presents information on the need to explore other non-traditional coping strategies not previously pursued to sustain the livelihoods of fishing communities. One such innovation is fish farming. In situating fish farming as a livelihood source to communities that live in the shores of Lake Malawi, this paper used a modified food systems perspective which also considers elements of the IPCC's vulnerability conceptual framework.

The results in this study showed that despite the proposed innovation being in peril of extreme weather events just like agriculture and capture fisheries, it could sustainably provide needed livelihoods. It might further cushion the effects of food insecurity and climate related changes while taking advantage of the water abundance in Lake Malawi's ecosystem. Furthermore, the paper shows that ownership of fish culturing facilities (earthen ponds) is dominated by men, despite the research area being dominated by matrilineal kinships. Similar findings were also reported in papers 1 and 2, where the act of catching fish revolved around men. Despite availability of land and water in the study area, in most cases the fish culturing units were smaller than the recommended sizes for profit and yield maximization. This could have been the reason as to why those engaged in fish farming did not consider it a major livelihood source when compared to agriculture, capture fisheries, and hunting. In addition, the majority of the fish farmers had either inherited the fish farms or were motivated by some development project to adopt fish farming. However, the probability to farm fish increased with an increase in water availability, purchasing staple foods in December, money spent on other non-staple foods, amount of cassava planted, and the number of fish harvested at one time during partial harvesting. On the other hand, that probability decreased with operating a bicycle taxi, prior participation in fish farming but not currently, amount of compost, rice bran applied in ponds, and providing casual labour in October.

The paper also reveals that low water flow in the study area coincided with the periods of extreme hot temperatures and low rainfall. These were also the periods in which most of the households faced

shortages in continuous food supply. The annual food supply varied among different food groups, with staple foods being least available compared to proteins that might have been supplied through either farmed or wild caught fish. The fish farming food system was also vulnerable to extreme weather events that resulted in fish mortalities, in addition to challenges in accessing quality fingerlings and feed.

These outcomes of the dominant food systems illustrated existence of weak synergies between fish farming and agriculture as they competed for production inputs, with the households opting to invest in agriculture. This however defeated the concept of sustainable use of byproducts and attaining sustainable diets. Furthermore, the potential of farming operations in influencing global environmental changes between the food systems was minimum due to low numbers of livestock, thereby decreasing methane production which is one of the greenhouse gasses.

The paper contributes to the potential of fishing farming as a livelihood strategy to communities that are used to fishing the wild environments. However, there are challenges that need to be sorted out before this dream can be realized. This is mainly focused on strengthening the supply chain of inputs and extension services.

7.4 Paper IV: Development initiatives, Livelihood Assets, and Adaptive Capacity among Lake Malawi Fishing Communities

Fish farming is an example of a development initiative. This final paper, also evaluated the probability which other groups of development initiatives such as access to health; access to formal credit; participation in infrastructure; employment; and improved food production and natural resource management programmes enhance adaptive capacity of vulnerable households along Lake Malawi. It is evident from this thesis that many of the coping strategies in use compromise the sustainability of natural resources. Due to such a vicious circle, and the need to improve social welfare of the local communities, many development projects have been implemented by both the state and non-state actors aimed to improve livelihoods. Despite such initiatives not being directly linked to reducing effects of climate related changes, they have potential to reduce vulnerability to other multiple stressors (Agrawala & Van Aalst 2008; Leichenko & O'Brien 2008; Leichenko *et al.* 2010; O'Brien 2012). However, there is a knowledge gap on the impact of such initiatives in reducing vulnerability of lakeshore communities of Lake Malawi. Therefore, in trying to understand such a knowledge gap, this article used the Sustainable Livelihood Framework (SLF) to conceptualize adaptive capacity (Gbetibouo & Ringler 2009; Nelson *et al.* 2010). The determinants for the adaptive capacity index were adapted from the SLF's five capitals (natural, social, physical, human and financial).

Though all vulnerable households wish to benefit from the development initiatives; this paper revealed that was not the case. Of the sampled households, about a third of them had benefited from any of the five groups of the initiatives. In addition, less female-headed households had been targeted to benefit from these initiatives. It is further noted that in all of the four papers, the role of women is minimal which poses challenges in reducing vulnerability against different shocks. Unlike the other three papers, this paper revealed an equal proportion of households had agriculture and fisheries as their main livelihood sources. However, the households that were targeted had less income from remittances and fisheries compared to the non-beneficiaries. These results imply that being a fisher reduced the chances of being targeted. Differences also existed between the beneficiaries and non-beneficiaries' socioeconomic characteristics such as land holding size, length of time stayed in the area, and net annual income. The beneficiaries had stayed longer than the non-beneficiaries had. This presence an element of permanent residence which could be viewed as social capital that mattered

most to be targeted. However, many studies in rural Malawi have also reported the importance of social capital in food security and economic welfare (Dzanja *et al.* 2013).

The paper further revealed that all of the five capitals significantly influenced adaptive capacity determination. Physical capital contributed more in the total variation of the adaptive index compared to the other capitals. This could be attributed to all respondents owning either a house or other property. The paper also significant differences between adaptive capacity for beneficiaries and non-beneficiaries of access to credit and infrastructural initiatives. Furthermore, the paper highlighted high income inequalities for both beneficiaries and non-beneficiaries. However, the inequalities leveled off with benefiting implying a positive impact of the development initiatives.

These findings are important in the conceptualization of adaptive capacity, which might require more emphasis to be placed on infrastructural initiatives. However, future research may need to explore differences between socioeconomic groups and how local institutions aid adaptation processes.

8. CONCLUSIONS

This thesis' main objective was to assess how local fishing communities are coping with climate related changes. While responding to this objective, multiple approaches and concepts were used to understand the underlying objectives. These objectives were thoroughly covered in four interlinked studies that explored different aspects of local fishing communities. This thesis has generated new knowledge on various aspects of inland fishing communities. Furthermore, the thesis places and contributes knowledge to both local and global discourse of inland small scale fisheries under the threat of global environmental changes and their related impacts. The contributions made by this thesis are broad and revolve around dominant narratives of climate change. The main empirical findings related to the research are outlined below.

Although the fishers claimed to be experiencing low fish catches due to changes in climate, fishing remained a major livelihood source. However, this thesis failed to validate such claims due to a lack of detailed fish stock assessment data for the study area. Even though there is an absence of stock assessment time series data, fishers' local knowledge on fish species and size composition is important as it reflects changes within the fishery. On the other hand, the perceived climate trends did not warrant any major changes as validated using climate data for the study area. Therefore, the fishers' perceptions should be considered with caution. While this thesis fails to ascertain the effects of climate change on fish catches, the use of unsustainable fishing methods were prevalent in the study area.

Despite no perceptual differences between men and women in changes related to fish catches, their views differed on certain aspects. One such case is on dominant fish species, as well as some ecosystem changes related to global environmental changes. Aspects of culture seemed to affect their coping processes due to assigned gender identities. These observed differences in how the respondents adjust to changes are important in informing gender-sensitive policies in natural resources management.

The adjustment mechanisms for the fishing communities were improving fishing effort by increasing fishing time and efficiency of fishing gear, farming, petty businesses, providing labour in fisheries and agriculture, migration to other fishing locations and fish landing grounds, offshore fishing, and selling fish in urban markets. Despite perceiving changes, other households did not adjust their behaviour. For example, some fishers continued benefitting from the fishery despite citing continued low fish catches. This means that the fishery was still their major livelihood source. Coping with these changes

increased with an increase in the household head's age, education level, and annual fishing income. Even though there were many different coping strategies, the thesis also reveals evidence of flexible livelihoods patterns through continuous movement of the fishing communities mainly between fisheries and agriculture. These shifts were partly influenced by proximity and the open access of the fisheries.

Managing these open access resources poses challenges which requires active participation of local communities as emphasized in the current legislature. This thesis showed that BVCs members had a lower propensity to cope with changes in fish catch than non-members. This could be because these members are committed to good fisheries governance and stick to their assigned mandate. Therefore, this thesis recommends strengthening these local fisheries management structures to improve fisheries productivity.

Strengthening local participation in sustainable fisheries exploitation should include all key players along the fish value chain as well as those associated with enjoying the benefits of the general ecosystem. This enables this thesis to use gender lenses in analyzing the roles of both women and men who are key stakeholders in the fishery. This thesis revealed a dividing line in terms of fish catching and post harvesting roles which are male and female dominated, respectively. Furthermore, there were changes in division of roles along the value chain, with more women venturing into what used to be traditionally male roles. Even with changes in division of roles, some roles remained male dominated such as fish catching. While women now own fishing equipment, they can not fish and instead employ fishers and a fishing crew to do so on their behalf. For women, such changes improved the socioeconomic status of their households. In addition, these changes were not a function of the perceived changes in climate.

Women were participating in fish value chain activities, however their participation in other livelihoods strategies was low, which presented potential to curb unsustainable exploitation of the lake resources. One such livelihood strategy evaluated in this thesis is fish farming, an innovation which is not promoted along the lakeshore communities due to available fish in the wild. Fish farming showed a great potential as a livelihood source for the communities in the study area, despite challenges in getting extension services, quality fingerlings, and feeds. The thesis also showed a potential to develop adaptive fish farming systems to cushion the perceived effects of extreme weather events. This

occurred despite the fact that fish farmers were not capitalizing on the synergies that existed between the various food systems due to competition for plant and animal residues, which are used as a form of fertilizer in agricultural fields.

Fish farming is an example of a development initiative that has its roots from the state and non-state actors' interventions to improve the livelihoods of vulnerable local communities. The thesis also evaluated the impact of other types of development initiatives in building adaptive capacity of vulnerable fishing communities along Lake Malawi. However, not every household benefited from the implemented initiatives. The thesis further reveals infrastructural group of initiatives amongst the analysed initiatives in improving adaptive capacity. This could be attributed to vulnerability of the study area as revealed in papers 1 and 2 due to extreme weather events. The initiatives had also the potential to reduce high-income inequalities prevalent in the study area. Therefore, in targeting vulnerable households, income inequalities could be used as a benchmark.

9. RECOMMENDATIONS

Having dispelled the dominant narrative of climate change due to failure to validate such claims, the thesis makes the following recommendations:

a. There is a need to expand research by using time series data for both climate and fish catches over a long period of time. Additionally, there is the need to model this relationship by including other water quality parameters that can enable proper ecosystem restoration.

b. There is also need to advocate for sustainable coping strategies as the frequencies of extreme weather events are projected to increase. Such strategies might include fish farming and adaptive capacity could be enhanced through the promotion of such initiatives.

c. There is also the need to expand this research by looking at linkages between other drivers responsible for reduced fish catches besides the dominant narratives of climate and overfishing. However, the assessments made in this thesis are a basis for any future intervention which could safeguard sustainable use of fisheries resources through adaptive management.

d. The research further shows the importance of livelihood diversification for communities that live along Lake Malawi. Therefore, this rich diversity stresses the need for a holistic ecosystem management strategy that encourages flexibility to venture into different coping strategies without limitations. Such flexibility also needs to include gender considerations even in areas where patrilineal kinship systems are dominant, because both men and women are major players in enhancing sustainable livelihoods.

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11. APPENDIX: Household survey questionnaires

Study 1: Household questionnaire

INFORMED CONSENT

Household identification and interview summary
101 District (name):_____ Code |____|____|
01= Nkhotakota
102 Region_____ Code|____|____|
01= Central
103 Respondent Code _____
104 Traditional Authority (name): _____ Code: |____|____|
105 Group Village Headman (name) _____Code: |____|____|
106 Village name: _____ Code: |____|____|
107 Research Assistant name _____
108 Questionnaire Number |____|____|____|____|
D D M M Y Y Y Y
109 Date of interview |__|___||___|___||___|___|___|___| Starting Time_____
To be completed after interview has been done
Peer Reviewed by….. D D M M Y Y Y Y
|____|____||____|____||____|____|____|____|
Name of Supervisor_____
Checked :_____ D D M M Y Y Y Y
|____|____||____|____||____|____|____|____|
Data Entry Clerk_____
Date of data entry _____

MODULE 2: HOUSEHOLD CHARACTERISTICS AND COMPOSITION

		A1[1)]	A2[2)]	A3	A4a[3)]	A4b[4)]	A5[5)]	A6
ID	Position in HH	Sex	Marital status	Age (yrs.)	Education	Other skills training	Main occupation	How long have you lived here (no of yrs.)
201	Head of HH							
202	Spouse							
203	Respondent not 201 or 202							

1) Codes: 1=male; 2=female

2) Codes: 1= single; 2=married; 3=divorced; 4=separated; 5=widowed; 6=cohabiting

3) Codes: 1= no formal education; 2=primary; 3=secondary; 4=higher education (college, university or similar)

4) Codes= 1=agricultural management skills; 2=fisheries management skills; 3=business skills; 4= other specify

5) Codes: 1=agriculture; 2=fishing; 3=hunting; 4 business, 5=house wife; 6= other specify

204. Please indicate the number of permanent household members in each group:

	Sex	Age group						
		0-10	11 - 20	21 to 30	31 - 40	41 - 50	51 - 60	Above 60
A.	Male							
B.	Female							

205. Why has the household head stayed this long in this area? _____

206. Where did the household head live before moving to this area? _____

(*If the household head has stayed in this since birth move to 209*)

207. Why did the household head leave the former place of residence? _____

208. What did the household head get after moving to this area? _____

209. What ethnic group or tribe do you belong to? _____

Note: The local team should define the different ethnic groups or tribes in the pilot area with code

1= Yao, 2 = Lomwe, 3 = Ngoni, 4 = Chewa, 5 = Tonga, 6 = Tumbuka, 7 = Sena, 8= Other (Specify)……

210. What religion do you practice? _____

Code: 1= Christian; 2=Muslim; 3=Buddhist; 4=Traditional animism; 5= other (specify):

6= No religion

211. Which year did you start fishing? ☐

212. Do you have access to safe water? 1=yes, 2=no ☐

213. Name the source of water and the distance from your house?

Water source	**Time taken to and from water source**	**Is water available throughout the year?, 1=yes, 2=no**	**Give reasons**
1.			
2.			
3.			

MODULE 3: HOUSEHOLD FISHING DATA

301. What type of fishing craft is owned by the household?
1 = Boat 2 = Boat with engine 3 = Dugout canoe 99 = Others (specify)

302. What type of fishing gears are owned by the household?					
Type of gear	**Number (#)**	**Mesh size (mm)**	**Length (m)**	**Depth (m)**	**Cost per gear (MK)**
Gill net					
Chilimira					
Beach seine net					
Mosquito net					
Fish traps					
Reed fence					
Hand line					
Long line					
Other specify					

303. What was the source of your capital for buying the fishing gears?

(*Multiple responses are allowed*)

1. Project
2. Fishing
3. Farming
4. Remittances from relatives
5. Credit/Loan
6. Employment
7. Casual Labour e.g. from fishing as crew members or ganyu in farming
8. Other, please specify

304. When was the fishing nets and crafts procured?

- Fishing net……
- Boat / Canoe ……...
- Engine Power and type……
- Fishing accessories……..

305. What was the QUANTITY and VALUE of fish caught from each of the fishing gear?						
Type of gear	Quantity LAST WEEK (No. of pails)	Value LAST WEEK (MK)	Quantity LAST MONTH (No. of pails)	Value LAST MONTH (MK)	Quantity LAST YEAR (No. of pails)	Value LAST YEAR (MK)
Gill net						
Chilimira						
Beach seine net						
Mosquito net						
Fish traps						
Reed fence						
Hand line						
Long line						
Other specify						

306. What are the common species composition of your catch?

1. Utaka; 2. Kampango; 3. Nkholokolo; 4. Chisawasawa; 5. Usipa; 6. Ncheni; 7. Ndunduma;

8. Sanjika; 9. Chambo; 10. Mlamba; 11. Mbaba

307. Where do you go for fishing?

1. Inshore area; 2. Offshore areas

308. How time does it take you to reach the fishing ground? ☐

309. How and why did you choose this particular fishing location?

Fishing location	Reasons for fishing ground selection
a.	
b.	
c.	
d.	
e.	

310. How long do you stay fishing using the fishing operation?

(1). 1 – 3 hrs (2). 4 – 6 hrs (3). 7 – 9 hrs (4). 10 – 12 hrs (5). Overnight ☐

311. What is the sharing arrangement of the landed catch?

312a. Are there any limitations to number of fishing vessels allowed to carry out fishing activities in this area?
(1) Yes (2) No ☐

312b.If yes explain……

313a. Are there any limitations to fishing vessels capacity limitations on engine power in this area?
(1) Yes (2) No ☐

313b. If yes explain…….
……..

314a. Are there any limitations to fishing gear limitation (number of type of fishing gear that can be used in a given area)?
(1) Yes (2) No ☐

314b. If yes explain……

315a. Are there any limitations to fishing effort limitation (e.g. days/hours of fishing allowed per year/season)? (1) Yes (2) No ☐

315b. If yes explain……

316a. Are there any limitations to fishing grounds limitations (e.g. areas where the use of specific fishing gear is interdicted)?
(1) Yes (2) No ☐

316b. If yes explain……

317a. Are there are controls on direct limits on the amount of fish coming out of a fishery?
(1) Yes (2) No ☐

317b. If yes explain……

318a. Has your fish catches and composition changed over the last two decades? 1. Yes; 2. No ☐

318b. If **YES**, what do you attribute such change in catches to? ***(Complete table below)***

Causes of decline in fish catches	Tick (Multiple response)	Rank these factors (Starting with 1 = most important, 2 = second most important, etc)
a. Changes in Lake Malawi Management		
b. Increased incidences too much rainfall		
c. Increased incidences too little rainfall		
d. Increased incidences hot weather		
e. High incidences of drought		
f. Economic situation in the country		
g. Poor access to fishing extension services		
h. Poor infrastructures services		
i. Low fishing knowledge		
j. No capacity to go offshore fishing		
k. Other 1. *(Specify)* ……		
l. Other 2. *(specify)* ……		
m. Other 2. *(specify)* ……		

319. What are the consequences of these changes to your livelihoods?

320. How often do you eat fish per week? ☐

321. Over the past five years, has your household run out of food? 1= Yes 2 = No ☐

322. What were the reasons for food shortage in your household? *(Multiple responses are allowed)*

1 = Drought **2** = Crop damage (pest & diseases) **3** = Land shortage

4 = Poor soils **5** = Excess rain **6** = Not enough rain

7 = Not enough labor **8** = Not enough seed **9** = Lack of fertilizer **10** = Sold most of the maize **11** = stolen **12** = Low fish catches **13** = Others (specify)

MODULE 4: HOUSEHOLD SOURCES OF INCOME

Ask the household head to rate the sources of income among different sources during the last five years.

401. Ranking of income sources for the past five years and cash income earned by the household.			
Source of income	**Rank during last FIVE YEARS**	**Income earned during LAST MONTH (MK)**	**Income earned during LAST YEAR (MK)**
I. Fishing			
Sale of fish			
Sale of fishing gear and fishing craft			
Casual employment in fisheries activities			
II. Farming			
Rainfed			
irrigation			
Sale of food crops			
Sale of cash crops			
Sale of fruits and vegetables			
Casual employment in farming activities			
I. Livestock			
Sale of livestock			
Sale of livestock products			
II. Off-farm activities			

Petty trade			
Business **(not fisheries or agriculture)**			
Other employment			
Wage			

402. **Welfare perceptions and social capital**

a. All things considered, how satisfied are you with your life over the past 12 months? *Codes: 1=very unsatisfied; 2=unsatisfied; 3=neither unsatisfied or satisfied; 4=satisfied; 5=very satisfied*		
b. Has the household's food production and income over the past 12 months been sufficient to cover the what you consider to be the needs of the household? *Codes: 1=no; 2=reasonable (just about sufficient); 3=yes*		
c. Compared with other households in the village (or community), how well-off is your household? *Codes: 1=worse-off; 2=about average; 3=better-off*		
e. How well off is your household today compared with the situation **5 years ago?** *Codes: 1=less well-off now; 2=about the same; 3=better off now*		
f. **If worse-** ***or*** **better-off:** what is the main reason for the change? *Please rank the most important responses, max 3.*	**Reason: Change in …**	**Rank 1-3**
	1. off farm employment	
	2. land holding (e.g., bought/sold land, eviction)	
	3. Fisheries resources	
	4. output prices (fisheries, forest, agric,…)	
	5. outside support (govt., NGO,..)	
	6. remittances	
	7. cost of living (e.g., high inflation)	
	8. war, civil strife, unrest	
	9. conflicts in village (non-violent)	
	10. change in family situation (e.g. loss of family member/a major bread-winner)	
	11. illness	
	12. access (e.g. new road,…)	
	13. increased/reduced land area for agric. production	
	14. religious awakening (i.e., found religion, converted to a new religion, born again or saved)	
	15. started a new business/lost or less business	
	16. livestock (gain or loss)	
	17. material assets, incl. house (gain or loss)	

	18. increased regulations	
	20. education / increased knowledge	
	21. more engaged in marketing/trade	
	22. political stability	
	23. crop failure/raiding	
	24. changed drinking habits (started/stopped drinking alcohol)	
	25. changes in natural resources (fish, etc.)	
	26. working for themselves (no longer under a *patron*)	
	27. more time to work	
	28. Joined cooperative	
	29. Forced to travel for family matters	
	30. Fire destroyed everything	
	31. Change in job	
g. Do you consider your village (community) to be a good place to live? *Codes: 1=no; 2=partly; 3=yes*		
h. Do you **in general** trust people in the village (community)? *Codes: 1=no; 2=partly, trust some and not others; 3=yes*		
i. Can you get help from other people in the village (community) if you are in need, for example, if you need extra money because someone in your family is sick? *Codes: 1=no; 2= can sometimes get help, but not always; 3=yes*		

MODULE 5: CLIMATE CHANGE RISKS

501. When did you first notice that there has been significant changes in climate/weather patterns? (Indicate the decade, e.g. 1980s)_____

502. How many drought/flood incidences have you witnessed in your lifetime?

(a) Drought incidences: *1=less than 3, 2= 4-6, 3= more than 6 incidences; 4 = Never witnessed* ☐

(b) Flood incidences: ☐ *1=less than 3, 2= 4-6, 3= more than 6 incidences; 4 = Never witnessed*

503. In which decade, would you say there has been frequent adverse weather events or climate / weather patterns in this area? *1= 1980s, 2= 1990s, 3= 2000s, 4= Other specify* ☐

504. Which years do you consider to have been dry in the past 20 years? _____

505. Which years do you consider to have been wet in the past 20 years? _____

506. Over the past five years, when did you experience these extreme weather events?

1= 2011 ☐ 2= 2012 ☐ 3= 2013 ☐ 4= 2014 ☐ 5= 2015 ☐

507. What type of extreme weather events have been common in this area in the last five years? *(Multiple responses are allowed).*

1= Increased drought incidences, 2= Increased flood incidences, 3= Extreme temperatures 4=Late rains 5=Dry spells 6=Early rains 7. Persistent winds

508. How often did you experience these extreme weather events?

1= 2011 2= 2012 3= 2013 4= 2014 5= 2015

509. What common damages/ losses do people in this area usually experience due to extreme weather events? *(Multiple responses are allowed)*

1= Crop damage; 2= Livestock loss; 3 = Loss of biodiversity; 4= Scarcity of water; 5= Low yields; 6. Low fish catches; 7 = Fishing vessels damage; 8. Fishing gear damage; 9 = Others specify

510. What have been the consequences of these extreme weather events to your livelihoods?

511. What are the observed changes in the rainfall patterns in the last 20- 30 years?

1= No changes; 2= late onset of season; 3= Early onset of the season; 4= erratic; 5= Poor distribution

What are the observed changes in the rainfall intensity in the last 20- 30 years?

1= Increasing; 2. = Decreasing; 3 = No change

512. Do you have access to the weather forecasting data/information from the meteorological? department? 1= yes 2= no

513. What is the source of this weather forecasting information? *(Multiple responses are allowed)*

1.= Radio station; 2. = Newspaper; 3. = Extension workers; 4. = Friends in the village; 5. = Household (Family) members; 6. = Church; 8. = Meteorological Station; *7. Other specify*

514. Do you know any traditional methods/indicators of predicting weather? 1= yes 2= no

515. If YES to 510 above, name these indicators/methods used to predict weather patterns

Weather pattern	**Prediction Indicators**
a. Drought Year	
b. Normal year (Rainfall)	
c. Flood Year	
d. Very cold winters	
e. Normal cold season	
f. Very hot summer	
g. Normal summer	
h. Windy	
i. No windy	

516. Have you ever lost a close relative during a fishing operation? 1= yes 2= no

MODULE 6: FISHER PERCEPTIONS OF CLIMATE & ECOSYSTEM CHANGES

601. Have you noticed any significant changes in weather patterns over the years in relation to fisheries? 1= yes 2= no

602. If **YES**, what changes have you observed?

1=increased drought incidences, 2=increased floods, 3=poor rainfall distributions, 4=extremes in temperatures (e.g. very cold winters/frost/very hot summer), 5= persistent mwera winds 6 = other (specify)

603. Which years did you get poor fish catches in the past 20 years? _____

604. What are the predominant fish species in the past 20 years?

605. Has any of these species disappeared?

606. What has caused this disappearance?

607. In your own view, what are the causes of fish catches variability or change?

608. What are the reasons for these ecological changes?

609. From the time you observed changes in climate (weather conditions); to what level have you observed a corresponding change in the following;

Variables	**Increased**	**Same**	**Declined**
a. Fish catches			
b. Fish biodiversity (species)			
c. Fish diseases			
d. Fish kills			
e. Ecosystem quality			

MODULE 7: ANALYSIS OF ADAPTATION MEASURES TO CLIMATE CHANGE

701. What are strategies and their challenges and constraints you put in place to adapt to the following climate changes related to fishing?

701a. Drought

701b. Floods

701c. Strong winds

701d. Heavy rainfall

701e. Heat waves

702.What role does the church/mosque play in conserving fisheries resources?

703.Do churches/mosques teach the consequences of climate change to your livelihoods?

704.What would you want the churches / mosques to do to curb these effects?

END OF QUESTIONS, THANK YOU VERY MUCH FOR YOUR TIME!

Study 2: Questionnaire

EFFECTS OF CHANGING LAKE DYNAMICS ON GENDER ROLES IN FISHING COMMUNITIES

INFORMED CONSENT

Household identification and interview summary
101 District (name):_____Code |____|____|
01= Nkhotakota
102 Region_____ Code|____|____|
01= Central
103 Traditional Authority (name): _____Code: |____|____|
104 Group Village Headman (name) _____Code: |____|____|
105 Village name: _____Code: |____|____|
106 Questionnaire Number |____|____|____|____|
D D M M Y Y Y Y
107 Date of interview |__|___||___|___||___|___|___|___| Time_____
To be completed after interview has been done
Peer Reviewed by….. D D M M Y Y Y Y
|____|____||____|____||____|____|____|____|
Name of supervisor_____
Checked :_____ D D M M Y Y Y Y
|____|____||____|____||____|____|____|____|
Data entry clerk_____ Date of data entry _____

MODULE 2: HOUSEHOLD CHARACTERISTICS AND COMPOSITION

		A1[1)]	A2[2)]	A3	A4a[3)]	A4b[4)]	A5[5)]	A6
ID	Position in HH	Sex	Marital status	Age (yrs.)	Education	Other skills training	Main occupation	How long have you lived here (no of yrs.)
201	Head of HH							
202	Spouse							
202	Co-wife							

1) Codes: 1=male; 2=female

2) Codes: 1= single; 2=married; 3=divorced; 4=separated; 5=widowed; 6=cohabiting,

3) Codes: 1= no formal education; 2=primary; 3=secondary; 4=higher education (college, university or similar)

4) Codes= 1=agricultural management skills; 2=fisheries management skills; 3=trading skills; 4 = other

5) Codes: 1=agriculture; 2= fishing; 3= business; 4= agriculture & fishing 5 = Business, fishing & agriculture
6 = others

203. Which type of kinship do you practice? .....

1. Patrilineal 2. Matrilineal

204. Why has the household head stayed this long in this area?

205. Where did the household head live before moving to this area?

206. Why did the household head leave the former place of residence?

207. What did the household head get after moving to this area?

208a. Has any member of your household migrated to other areas? …….

1. Yes 2. No

208b. If yes, was it permanent migration or temporary? 1. Permanent 2. Temporary ……

208c. Where did they migrated to?

1. Central Business District (Boma) 2. Another district in Malawi 3. South Africa 4. Other specify

208d. What was the purpose of migration?

209. Please indicate the number of permanent household members in each group:

	Sex	Age group						
		0-10	11 - 20	21 to 30	31 - 40	41 – 50	51 - 60	Above 60
A.	Male							
B.	Female							

210. What ethnic group or tribe do you belong to? _____

Note: The local team should define the different ethnic groups or tribes in the pilot area with code

1= Yao, 2 = Lomwe, 3 = Ngoni, 4 = Chewa, 5 = Tonga, 6 = Tumbuka, 7 = Sena, 8= Other (Specify)……

211. What religion do you practice? _____

Code: 1= Christian; 2=Muslim; 3=Buddhist; 4=Traditional animism; 5= other (specify):

6= No religion

212. What type of house do you have? …….

1. Brick grass thatched 2. Brick iron sheets 3. Mud grass thatched

213. Who owns the house?

1. My husband 2. My wife 3. My parents 4. Land lord 5. My father in-law 6. My mother in-law 7. Others - specify

214. Are you renting? …… 1. Yes 2. No

215. How much is the monthly rent? MK…….

216. Does your household have the following assets? (Please read out the list)

Type of asset	Record **1 = Yes** and **2 = No**	**Number in possession**
Plough/Ridger		
Radio		
Wheelbarrow		
Shovel/pick		

Treadle pump		
Bicycle		
Cell phones		
Sewing machines		
Ox-cart		
Axe		
Hoe		
Panga		
Sickle		
Motorized pump		
TV		
Mattress		
Tables		
Iron roofed		
Electricity		
Solar panels		

MODULE 3: HOUSEHOLD FISHING DATA

301. What type of fishing craft is owned by the household? …….
1 = Wooden plank boat 2 = Wooden plank boat with engine 3 = Dugout canoe 4 = others (specify)

302. What type of fishing gear is owned by the household?						
Type of gear	Number (#)	Mesh size (mm)	Length (m)	Depth (m)	Who owns?	Who use?
Gill net						
Cast net						
Fish traps						
Seine net						
Hand line						
Reed fence						
Scoop net						
Long line						
Mosquito nets						

303. What are the five most common fish species caught in this area? ……...

1. Utaka 2. Usipa 3. Nkholokolo 4. Chambo 5. Mbaba 6. Chisawasawa 7. Kampango 8. Ncheni 9. Ndunduma 10. Sanjika

11. Mpasa 12. Milamba 13. Sapuwa 14. Nkolokolo 15. Other specify

304. Which species do you consume most?

305. How many times do you eat fish in a week?

306. Which species of fish do you commonly sell?

This should apply to the most caught fish species as informed from above

307. What was the QUANTITY and VALUE of fish caught from each of the fishing gear?							
Type of gear	**Species (use codes below)**	**Quantity LAST WEEK (kg/pails /dozens)**	**Value LAST WEEK (MK)**	**Quantity LAST MONTH (kg/pails /dozens)**	**Value LAST MONTH (MK)**	**Quantity LAST YEAR (kg/pails /dozens)**	**Value LAST YEAR (MK)**
Gill net							
Cast net							
Fish traps							
Seine net							
Hand line							
Reed fence							
Scoop net							
Long line							
Mosquitoes							

1. Utaka 2. Usipa 3. Nkholokolo 4. Chambo 5. Mbaba 6. Chisawasawa 7. Kampango 8. Ncheni 9. Ndunduma 10. Sanjika 11. Mpasa 12. Milamba 13. Sapuwa 14. Nkolokolo 15. Other specify

308. How much of your monthly income came from fishing and fish sales?

Month	**Amount per month**	**Proportion of money from fisheries**
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
January		
February		

309. What type of fish products do you sell?

310. Which fish value chain are you involved in? …….

1. Catch and sell fish
2. Catch, process and sell
3. Purchase, process and sell
4. Processing and sell

311. What type of fish products do you consume?

312a. Are there any new stakeholders coming in the fishing industry? 1. Yes 2. No ……..

312b. If yes why

312c. Where are they coming from? ……

312d. What is their role in the value chain?

313. Where do you sell your fish? ……..

1. Village market 2. At the landing site 3. District market 4. Out of the district
5. To vendors

314. What is the cost structure of the following:

a. Buying a boat / canoe……
b. Buying nets……
c. Labor per fishing trip…….
d. Fuel per fishing trip……
e. Food for the crew per fishing trip……..

MODULE 4: PERCEPTIONS ON CLIMATE & ECOSYSTEM CHANGES

401. Have you noticed any significant changes in weather patterns over the years in relation to fisheries? 1= yes 2= no

402. If **YES**, what changes have you observed?

1=increased drought incidences, 2=increased floods, 3=poor rainfall distributions, 4=extremes in temperatures (e.g. very cold winters/very hot summer), 5= persistent mwera winds 6 = other (specify)

403. Which years did you get poor fish catches in the past 20 years?

404. What are the predominant fish species in the past 20 years?

405. Has any fish species disappeared?

406. What has caused this disappearance?

407. In your own view, what are the causes of fish catches variability or change?

408. From the time you observed changes in climate (weather conditions); to what level have you observed a corresponding change in the following.

Variables	**1. Yes 2. No**	**Increased**	**Same**	**Declined**
a. Beach size				
b. Coastal area				
c. Number of trees				
d. Reeds				
e. Wetlands				
f. Rivers flow				
g. Size of rivers (depth & width)				
h. Soil type				
i. Vegetation				
j. Ecosystem quality				
k. Fish kills				

409a. How have you adapted to these changes?

409b. Of the strategies listed above, rank them according to their importance and frequency of usage?

410. Are there any innovative ways to adapt to these changes?

411. What have been the challenges to your adaptation strategies?

MODULE 5: FISHING GENDER ROLES

501a. What are the different activities in the value chain for each of the three most caught species mentioned above? Probe these from the household – Do not mention these to them, but they should list these activities per the three most caught species. **Species name……**

Activity	Male	Women	Laborer	Who does it most?	Who is most knowledgeable in the activity?	When are these activities conducted?	Are they any changes in who was doing this in the past?	What are the reasons for this change?
a. Identification of fishing ground								
b. Buying nets								
c. Buying boats								
d. Buying of fuel								
e. Identification of fishing crew								
f. catching of fish								
g. Grading of fish								
h. Selling of fish								
i. Process of fish								
j. Selling to uptown markets								
k. Who has the right to use the catch?								
l. Who controls the proceeds from the catch?								
m. Who decides how much to use?								

1. Utaka 2. Usipa 3. Nkholokolo 4. Chambo 5. Mbaba 6. Chisawasawa 7. Kampango 8. Ncheni 9. Ndunduma 10. Sanjika 11. Mpasa 12. Milamba 13. Sapuwa 14. Nkolokolo 15. Other specify

502. What are the implications of the above changes on gender roles and women's control of resources?

MODULE 6: HOUSEHOLD SOURCES OF INCOME

Ask the household head to rate the sources of income among different sources during the last five years.

701. Ranking of income sources for the past twenty years and cash income earned by the household.			
Source of income	**Rank during last twenty years**	**Income earned during last year (MK)**	**Income earned during last month (MK)**
I. Fishing			
Sale of fish			
Sale / leasing of fishing gear and fishing craft			
Casual employment in fisheries activities			
II. Farming			
Rainfed			
irrigation			
Sale of food crops			
Sale of cash crops			
Sale of fruits and vegetables			
Casual employment in farming activities			
III. Livestock			
Sale of livestock			
Sale of livestock products			
IV. Off-farm activities			
Petty trade			
Business **(not fisheries or agriculture)**			
Other employment			
Wage			

MODULE 7: ADAPTATION STRATEGIES TO LAKE DYNAMICS.

801a. Has changes in lake dynamics affected / impacted women's livelihoods? ……

1. Yes 2. No

801b. If yes, how has these changes affected women?

802. What are the coping mechanisms being used by women to adapt to these changes?

803a. Are there any differences in the way adaptation is happening as compared to the past? 1. Yes 2. No …….

803b. If yes, explain these changes.

804a. Has these changes affected fishing activities done by women? 1. Yes 2. No ……

804b. If yes, explain these changes

805a. Has these changes affected ownership of resources by women? 1. Yes 2. No

805b. If yes, explain these changes

806a. Has changes in lake dynamics affected / impacted men's livelihoods?

1. Yes 2. No

806b. If yes, how has these changes affected men?

807. What are the copying mechanisms used by men to adapt to these changes?

808a. Are there any differences in the way adaptation is happening as compared to the past? 1. Yes 2. No ……..

808b. If yes, explain these changes

809a. Has these changes affected fishing activities done by men? 1. Yes 2. No ……...

809b. If yes, explain these changes

810a. Has these changes affected ownership of resources by men? 1. Yes 2. No

810b. If yes, explain these changes

811.What are the challenges you are facing in adapting to the changes?

END OF QUESTIONS, THANK YOU VERY MUCH FOR YOUR TIME!

Study 3: QUESTIONNAIRE

THE EFFECT OF CLIMATE VARIABILITY ON SMALL-SCALE FISH FARMING

INFORMED CONSENT

Household identification and interview summary
101 District (name):_____Code |____|____|
01= Nkhotakota
102 Region_____ Code|____|____|
01= Central
103 Respondent Code_____
104 Traditional Authority (name): _____Code: |____|____|
105 Group Village Headman (name) _____Code: |____|____|
106 Village name: _____Code: |____|____|
107 Research Assistant Name _____
108 Questionnaire Number |____|____|____|____|
D D M M Y Y Y Y
109 Date of interview |__|___|___|___|___|___|___| Starting time_____
To be completed after interview has been done
Peer Reviewed by….. D D M M Y Y Y Y
|____|____|____|____|____|____|____|____|
Name of supervisor_____
Checked :_____ D D M M Y Y Y Y
|____|____|____|____|____|____|____|____|
Data entry clerk_____
Date of data entry _____

MODULE 2A: HOUSEHOLD COMPOSITION

		A1[1)]	A2[2)]	A3	A4a[3)]	A4b[4)]	A5[5)]	A6
ID	Position in HH	Sex	Marital status	Age (yrs.)	Education	Other skills training	Main occupation	How long have you lived here (no of yrs.)
201	Head of HH							
202	Spouse							
203	Respondent not 201 or 202							

1) Codes: 1=male; 2=female

2) Codes: 1= single; 2=married; 3=divorced; 4=separated; 5=widowed; 6=cohabiting

3) Codes: 1= no formal education; 2=primary; 3=secondary; 4=higher education (college, university or similar)

4) Codes= 1=agricultural management skills; 2=fisheries management skills; 3=business skills; 4= other specify

5) Codes: 1=agriculture; 2=fishing; 3=hunting; 4 business, 5=house wife; 6= other specify

MODULE 2B: HOUSEHOLD STRUCTURE

(Include all members who are largely dependent on the household head for livelihoods)

Category of household/s members	**Male**	**Female**
204. Number of children under the age of 15 years		
205. Number of elder persons (70+ years) in the household		
206. Number of adults (between ages of 15 and 70 years) who are largely unable to assist the household with its farming activities due to ill health or disability		
207. Number of able bodied adults (15-70 yrs) **present** in the household		
208. Number of adult members of the household who are **absent** and dependent on the household for support		

MODULE 3: HOUSEHOLD ACCESS TO AND USE OF LAND AND NATURAL RESOURCES

Access to and use of grazing resources

301. Indicate the number of the different types of livestock the household has and uses to provide for their food and income requirements:

Livestock type	**Number**
Cattle	
Goats	
Sheep	
Donkeys	
Pigs	
Chickens (& other birds)	

Other:	

302a. Do you have access to grazing land?

Yes	No

302b. If yes, is this land communally owed or your own?

Communal	Own

303. Indicate the quality of the grazing land available to the household:

Poor	Good	Excellent

304. Access to arable land and use of this land

(Due to different measures [hectares and acres] of land area the enumerators need to be able to estimate areas of land independently from the respondent) Note that 1 hectare = 2.4 acres

Characteristics	Arable Area 1	Arable Area 2	Arable Area 3	Arable Area 4	Arable Area 5	Arable Area 6	Arable Area 7
Size/Area (acres)							
Soil Quality							
Irrigated Y/N							
305.	Indicate below the proportion (%) of field (or area) planted to each crop during this 2015/2016 growing season (more than one crop can be grown in any field). Also, the quantity of each crop harvested from each land area per year should be indicated. Care should be taken to determine the measure that these quantities are represented in. For example, 50kg or 90kg bag of maize.						

	%	Yield	%	Yield	%	Yield	%	Yield	%	Yield	%	Yield	%	Yield
a. Summer Maize														
b. Winter Maize														
c. Cassava														
d. Millet														
e. Sorghum														
f. Wheat														
g. Beans														
h. Soya beans														
i. Pigeon peas														
j. Ground-nuts														
k. Peas														
l. Pumpkins														

Characteristics	Arable Area 1		Arable Area 2		Arable Area 3		Arable Area 4		Arable Area 5		Arable Area 6		Arable Area 7	
m. Pineapple														
n. Vegetables														
o. Tobacco														
p. Coffee														
q. Bananas														
r. Mangos														
s. Cotton														
t. Other specify														
u. Other specify														

306. What are amounts of fingerlings, seed, fertilizers and chemicals/pesticides applied in field?

Crop	**Seed amount used**		**Fertilizer amount applied**			**Chemicals/pesticides amount applied**		
	Unit	Amount	Type	Unit	Amount	Type	Unit	Amount
Fingerlings								
Maize								
Rice								
Cassava								
Tomato								
Tobacco								
Fish								
Other specify								
Other specify								

307. UNUSED LAND

Characteristics	**Unused land**	**Rented to someone else**
Size/Area (acres)		
Soil Quality		
Potential for irrigation	Y/N	

ACCESS TO WATER

308. Do you have access to water for cultivation and/or ponds?

Yes	No

309. Where do you source this water from:

Individual furrow from a river/stream	From a shared irrigation furrow	Furrow from a spring	Well	Ground water seepage

310. Indicate the relative amounts of water you have access to for irrigation and/or ponds during each Month of the year.

		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Relative Amount	Irrig.												
	Ponds												

To indicate relative amount, ask respondent to rank the water supply for each month from 0 – 1. (0 being no flow and 1 being the strongest flow)

311. If the supply of water is variable, what are the factors that cause this variability?

Rainfall (flood/drought)	Stream flow	Competition from other users	Seepage from furrow	Evaporation

312. Is there enough water available to support additional ponds and/or larger areas of irrigated cultivation?

Yes	No

313. If there is enough water to allow expansion, what would be the preferred use for this water?

1. Irrigated cultivation	2. Fish Ponds	3. Other

MODULE 4: HOUSEHOLD LIVELIHOODS AND WEALTH INDICATORS

401. Indicate in the table below the sources of income obtained by the households and the relative proportions that each of these sources contribute to total household income.

Indicate in the table below the period of the year in which each source of income is received or generated.

Source of household income	**Tick if Yes**	**Contribution to total annual household income (%)**	**Period during which this income is received**
a. Full-time formal employment			
b. Part-time formal employment			
c. Owner business (artisan, shop-keeper, taxi driver, etc)			
d. Casual/temporary off-farm employment			
e. Seasonal farm employment for money			
f. Pension or Welfare grant			
g. Remittances			

Source of household income	Tick if Yes	Contribution to total annual household income (%)	Period during which this income is received
h. Sale of tobacco			
i. Sale of coffee			
j. Sale of fruit and vegetables			
k. Sale of food crops (Maize, cassava, beans, groundnuts, pumpkins, etc)			
l. Sale of cotton			
m. Sale of cattle, sheep or goats			
n. Sale of pigs and chickens			
o. Sale of milk and eggs			
p. Sale of hides and skins			
q. Sale of fish			
r. Rent			
s. Other			
Total		(100%)	

402. Indicate the proportion of income spent on the following items:

Expenditure Items	Proportion of annual income spent (%)
a. Education (fees + uniforms, etc)	
b. Transport	
c. Maize, cassava or rice for household consumption	
d. Fish for hh consumption	
e. Other foods for hh consumption	
f. Building materials	
g. Clothing & blankets	
h. Furnishings and domestic utensils	
i. Tools and inputs for productive activities	
j. Luxuries (non-essential items)	
k. Labour	
l. Rents	
m. Others	

403. Does the household have the following assets: (tick those they have)?

Asset name	Quantity	Year purchased / given	Cost of asset

a. Radio/music player			
b. Bicycle			
c. Motor Vehicle			
d. Tractor			
e. Net for fish harvesting			
f. Wheel-barrow			
g. Oxcart			
h. Iron sheets on house			
i. Hoes (number?)			
j. Others			

MODULE 404: FOOD SECURITY

401a. Are there periods during the year when your household has nothing or very little food to eat from on-farm production?

Yes	No

401b. If yes, please indicate these periods in the table below and rank the degree of on-farm food shortage from 0-3. Zero (0) = no lack of food, 1 = a lack of protein (relish) but no shortage of other foods, 2 = no staple but other sources of relish and vegetables, 3 = no staple food or other sources of food.

401c. Please also indicate in the table when it is necessary to buy staple foods such as maize, cassava or rice for household consumption. (Tick months when staple food needs to be bought)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Own food												
Buy												

402a. Does the household engage in Ganyu?

Yes	No

402b. Indicate the periods of the year when Ganyu is engaged in.

Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May

403. Based on the discussions held with the farmer and observation of the household, enumerators are to provide a general opinion as to the level of food security that a household enjoys. (This is used simply to back-up the information recorded in 26 above and does not replace it.)

1. Food secure	2. Partially food secure	3. Food insecure

MODULE 5: FISH FARMING ACTIVITIES

501a. Are you currently involved in fish farming?

Yes	No

If no:

501b. Have they been involved in fish farming before (during earlier period)?

Yes	No

If yes:

501c. During what period did they engage in fish farming?

501d. Why did they stop fish farming?

If they are currently involved in fish farming:

502. Why did they first become involved in fish farming?

a. Fish farming Project	b. Self-motivation	c. Inheritance	d. Other

503. Are you a member of a fish farming club?

Yes	No

504. What are the conditions for one to be a member?

505. What are services provided by the club?

506. How has these services improved your livelihoods?

If they are currently or were previously involved in fish farming:

507. From whom/where did they get the information and advice they needed to start and maintain fish farming?

Source of Information	**Tick**
a. Father/Grandfather/Uncle/Guardian	
b. Discussion with neighbours	
c. Observation of neighbours	
d. Fish Farmers Club	
e. Fisheries Extension Officer	
f. Project/NGO g. Name Project:	
h. Reading material	
i. Radio	
j. School	
k. Fish farming training (From whom?):	

Respondent may indicate more than one source of information

508a. Who in the household is mainly responsible for the fish farming activities?

1. Head of Household	2. Another household member

508b. **If** the person mainly responsible for the household's fish farming activities is **not the head of the household (respondent)** please provide the details of the person responsible in the table below:

Person Responsible for Fish Farming	**Characteristics**
a. Age	
b. Male / Female	
c. Highest level of education	
d. Relationship to household head	

Fish Ponds

509. To be answered by those currently involved in fish farming as well as those who may have been engaged in fish farming in the past (but not currently).

Characteristics	**Pond 1**	**Pond 2**	**Pond 3**
a. How did you get a pond?			
b. Year of construction			
c. Cost for each (MK)			
d. Length of pond			
e. Breath of pond			
f. Date of last stocking			
g. Number of each species put into pond at last stocking	TR = OS = CG= OK = CC =	TR = OS = CG= OK = CC =	TR = OS = CG= OK = CC =
h. Month and year of last large harvest			

Choices for a & g

a: How did you get a pond? 1 = inherited; 2 = Self constructed; 3 = constructed with paid labour; 4 = Project constructed; 5 = taken over from somebody else (though sale, gift or transfer, etc)

g: Species: TR = *Tilapia rendalli (Chilinguni); OS = Oreochromis shiranus (Makumba); CG = Clarias gariepinus (Mlamba) OK = Oreochromis karongae (Chambo), CC = Cyprinus carpio*

510. Do you want to expand your fish farming operations?

Yes	No

511. If you wanted to construct more ponds in the future, would you be able to access land with a continuous water supply?

Yes	No	Unsure

Fish Farming Objectives

512. What are, or were your objectives for your fish farming activities?

Type of Objective	Tick
a. To provide the households with a source of protein	
b. To diversify the household's food sources.	
c. To produce fish for distribution to family, friends and neighbours for the purpose of building and strengthening social relationships	
d. To produce fish for sale to generate income	
e. To increase the social status of the household/person	
f. Because you are interested in it (Hobby) or want to experiment with new productive activities	
g. For educational and community development purposes.	
h. Other	

Sources of fingerlings

513. Where have they obtained fingerlings?

Source of fingerlings	Tick	Species
a. Donations from neighbours/kin		
b. Purchase from neighbours		
c. Purchase from other fish farmers (Who?)……..		
d. Purchase from Department of Fisheries (Where?)……		
e. Self-production		
f. Other		

514. Indicate in the table below whether it is difficult to get access to different types of fingerlings or not and why.

Species	Difficult Y/N	Why?
a. TR		
b. OS		
c. CG		
d. OK		
e. CC		

515a. What is the your preferred species for fingerlings? ……

515bWhy? …….

FISH FEEDING ACTIVITIES DURING THE LAST YEAR

517. Indicate the relative amount of each food source fed to fish in each month. Rank the supply of each feed source for each month from 0–2. (2 being the largest quantity of feed)

Food Source	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
a. Manure (type)……..												
b. Compost												
c. Maize bran												
d. Rice bran												
e. Cassava												
f. Soya												
g. Leaves/ Grass												
h. Vegetable matter												
i. Other:												

Manure types: Goat = 1; chicken = 2; cow = 3; pig = 4; rabbit = 5; Other = 6

517. Do you provide your fish with supplementary feeds? |____| 1) Yes 2) No

518a. Do you give mineral premixes to your fish? |____|____|

1. Yes 2. No

518b. If yes, what is the source of the premix?

519. What is the cost of the mineral premix |____|____|packet

520. Do you face any problems with supplements feeding? |____|____|

1) Yes 2) No

521. What are the problems with supplement feeding?

1) High Cost of feed

2) Inadequate availability

3) Inconsistent supply

4) Other specify_____

523. How do you treat disease outbreak of your fish |____|____|

1. Yes 2. No

524. How often are your fish attacked by diseases? |____|____|

525a. Do you face major problems on disease disorders and treatments?

1. Yes 2. No

525b. If yes, what could be the possible cause of the case? |____|____|

1) Fleas

2) Feeding (nutritional problems)

3) Worms

4) Injury

5) Calving (dystocia)

6) Other specify

524c. Number of treatments per growing season|____|

524d. Total costs per growing season |____|____|

Harvesting of Fish

525. Which fish harvesting methods do you use?

a. Break dyke / total pond drainage	b. Seine nets (less than 1 inch)	c. Seine nets (more than 1 inch)	d. Hook & Line	e. Basket	f. Reed fence

526. If you have harvested using a net, do you own this net or did you hire/borrow it?

Own Net	Hired/Borrowed Net

527. From whom did you hire or borrow the net?

528. Do you keep records of your fish harvests?

Yes	No

529 Enumerator to ask if he can have a look at these records and rank the quality of these records.

a. Good	b. Poor	c. No Records

530a. Does the price that you receive for the same weight of small and large fish differ when you sell your fish?

Yes	No	Don't know

530b. If yes, for which do you receive a higher price?

Large	Small

530c. If you partially harvest fish from the pond/s for home consumption, how often do you catch fish in this way for each month of the last year?

Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May

For each month indicate whether partial harvesting takes place on a daily, weekly, monthly or irregular basis, or not at all. D = Daily, W = weekly, M = monthly, I = irregularly. No fishing = N

530d. How many fish do you catch at any one time when you partial harvest for home consumption?

530e. What is the average size of the fish caught when you partial harvest for home consumption?

(Enumerator to obtain measure in hands and record in cm)

FISH PRODUCTION AND MARKETING

531. Production and utilization

Year	**Unit**	**Production**	**HH consumption**	**Quantity sold**	**Unit price**	**Total value**	**Who buys? (See codes)**
2011							
2012							
2013							
2014							
2015							

Codes. 1 Community members, 2 super markets/shops, 3 institutions, 4 other specify

532a. Do you produce fingerlings? (**Use code**: 1 = yes, 2 = No) _____

532b. If yes, proceed to the table below.

Year	Unit	Quantity sold	Unit price	Total value	Who buys? (See codes)
2011					
2012					
2013					
2014					
2015					

Codes. 1 Fellow farmers, 2 NGOs/CBOs, 3 research institutions, 4 other specify

LABOR COSTS

533. Who is normally involved in farming activities? |____|____|

a. Family members
b. Casual worker
c. Both

534a. If Casual: Labour; How much do you pay for casual labour/day (Or per month)? MK_____

534b. Estimated Annual Cost……

INFORMATION ON FISH MARKETING (for the past 12 months)

535a. Where do you sell your fish? |____|____|

1. Urban markets 2. Middle men 3. Within the village 4. Other specify Local Market 5. Other specify_____

535b. What are the reasons for selling fish at this market? |____|____|

1. Better prices, 2. NGO encourages it, 3. Direct cash payment, 4. Closer to the farm

535c. How far are you from the nearest market? |____|____|

1. <1km 2) 1-1.9km 3) 2-2.9km 4) 3-3.9km 5) 4-4.9km 6. >5km

535d. How much do you pay for transporting fish to the market place? (If applicable) MK_____

535e. What was the average price of fish for the past 12months? MK |____|____|/ piece or Kilogram

536. What problems do you face with the marketing of your fish |____|____|

1. low fish prices

2. long distance

3. late payments

4. leadership at the club

5. Other (Specify)_____

537. Which activity (ies) attract much costs on your fish farm?

1) Feed

2) Physical structures

3) Marketing costs

4) Labour

5) Other (Specify)_____

ACCESS TO EXTENSION SERVICES & CREDIT

538. Do you have access to extension services? |____|____|

1) No 2) Yes

539. Who provides fish farming extension services? |____|____|

1.) Government 2) NGO (Specify) _____ 3) Both

540. How often are you visited by extension agents per month?

541a. Do you have lead farmers for fish farming? |____|____|

1) No 2) Yes

541b. If yes, explain how they are selected.

542. What is the role for these lead farmers in fish farming?

543. Do you think the lead farming model is very important in fish farming?

544. Level of adoption of aquaculture technologies

No.	Aquaculture technologies	Level of Adoption of technologies [1])	Source of technology	Year
a.	Integrated fish farming			
b.	Use of manure in ponds			
c.	Direct feeding of fish with formulated feeds			
d.	Direct feeding of fish with maize bran			
e.	Direct feeding of fish with vegetables			
	Direct feeding of fish with indigenous feeds			
f.	Cleaning the ponds after harvest			
g.	Using PVCs for outlets and inlets			
h.	Improved fish breeds (Makumba)			
i.	Use of indigenous technology to improve pond buffer system (use of ash)			
j.	Use of harpa system for breeding			
Others				

Level of Adoption of technologies [1]) : 1 = Adopting, 2 =Not Adopting

545. How does knowledge on new fish farming technologies trickle down to you?

546. Does fish farming have different extension agents as compared to agriculture?

547. Are you involved in on-farm research? If yes, explain how you were selected.

548. What are the major problems faced by extension agents?

549. Do you think the way information is disseminated in fish farming needs improvement. Please explain your response.

550a. Do you have access to credit for your fish enterprise?

1) Yes 2) No

552b. If yes, what type of loan?

1) seed scheme

2) cash loan

3) Feed loan

4) other loans (specify)_____

550c. What is the source of that loan?

Other (Specify)_____

551. What are the key challenges in your fish production enterprise (in order of importance)?

FISH CAPTURING

552a. Do you think it is better to combine capture fisheries and fish farming?

Yes	No

552b. If yes, please explain…….

PERCEPTIONS OF FISH FARMING ACTIVITIES

553a. Are you satisfied with your current fish production?

Yes	No

553b. If no, why?

554. What specific issues do you think need to be addressed in order for you to be more successful at fish farming?

MODULE 6: CLIMATE CHANGE RISKS

601. What are the biophysical changes that have occurred in the last 20 years?

602. What are the impacts of these biophysical changes to your fish ponds and the community at large?

603. When did you first notice that there has been significant change in climate/weather patterns? (Indicate the decade, e.g. 1980s)_____

604. How many drought/flood incidences have you witnessed in your lifetime?

(a) Drought incidences: *1=less than 3, 2= 4-6, 3= more than 6 incidences; 4 = Never witnessed*

(b) Flood incidences: *1=less than 3, 2= 4-6, 3= more than 6 incidences; 4 = Never witnessed*

605. In which decade, would you say there has been frequent adverse weather events or climate / weather patterns in this area? *1= 1980s, 2= 1990s, 3= 2000s, 4= Other specify*

606. What type of extreme weather events have been common in this area in the last five years?

(Multiple responses are allowed).

1= Increased drought incidences, 2= Increased flood incidences, 3= Extreme temperatures

4=Late rains 5=Dry spells 6=Early rains

607. Do you have access to the weather forecasting data/information from the meteorological?

608. department? 1= yes 2= no

608. What is the source of this weather forecasting information? *(Multiple responses are allowed)*

1.= Radio station; 2. = Newspaper; 3. = Extension workers; 4. = Friends in the village;

5. = Household (Family) members; 6. = Church; 8. = Meteorological Station; *7. Other specify*

609. Do you know of any traditional methods/indicators of predicting weather? 1= yes 2= no

610. If YES to 1009 above, name these indicators/methods used to predict weather patterns

Weather pattern	**Prediction Indicators**
Drought Year	
Normal year (Rainfall)	
Flood Year	
Very cold winters	
Normal winters	
Very hot summer	
Normal summer	

611. Over the past five years, when did you experience these extreme weather events?

1= 2011 ☐ 2= 2012 ☐ 3= 2013 ☐ 4= 2014 ☐ 5= 2015 ☐

612. How often did you experience these extreme weather events?

613. What common damages/ losses do people in this area usually experience due to extreme weather events?

1= Crop damage |___| 2= Livestock loss |__| 3 = Loss of biodiversity |___| 4= Scarcity of water |___| 5= Low yields |__| 6. Low fish catches |__| 7 = Fishing vessels damage |__| 8. Fishing gear damage |__| 9 = Others specify

614. How has the prolonged dry spells affected your fish farming?

a. Negative	b. Positive
1. _____	1 _____
2. _____	2 _____
3. _____	3 _____

615. What are the observed changes in the rainfall patterns in the last 20- 30 years?

1= No changes |___| 2= late onset of season |___| 3= Early onset of the season |___| 4= erratic |___| 5= Poor distribution |___|

616. What are the observed changes in the rainfall intensity in the last 20- 30 years?

1= Increasing |___| 2. Decreasing |___| 3. No change |___|

MODULE 7: PERCEPTIONS ON CLIMATE & ECOSYSTEM CHANGES

701. Have you noticed any significant changes in weather patterns over the years in relation to fish farming?

1= yes 2= no

702. If **YES**, what changes have you observed?

1=increased drought incidences, 2=increased floods, 3=poor rainfall distributions, 4=extremes in temperatures (e.g. very cold winters/frost/very hot summer), 5= persistent mwera winds 6 = other (specify)

703. Which years did you get poor fish production in the past 20 years? _____

704. In your own view, what are the causes of fish production variability or change?

705. From the time you observed changes in climate (weather conditions); to what level have you observed a corresponding change in the following;

Variables	**Increased**	**Same**	**Declined**
a. Fish catches			

b. Aquatic biodiversity			
c. Fish diseases			
d. Fish kills			
e. Ecosystem quality			

706. Has there been any changes to the ecosystem on the following:

Variables	Increased	Same	Declined
a. Number of trees			
b. Reeds			
c. Wetlands			
d. Rivers flow			
e. Size of rivers (depth & width)			
f. Soil type			

MODULE 8: ANALYSIS OF ADAPTATION MEASURES TO CLIMATE CHANGE

801. What strategies have you put in place to adapt to climate change?

Risks	Strategies (Use codes below and fill each box, multiple answers possible)				
Drought					
Floods					
Strong winds					
Other____					

Code: 1=crop diversification, 2 =adjusting timing for farm operation, 3=Changes in tillage practices, 4= Irrigation , 5 =Efficient water use, 6=food rationing , 7 =digging deeper wells , 8 =rent , 9 =casual labor, 10= selling livestock , 11=IGA , 12= charcoal burning, 13= use of wild plant , 14= fishing, 15= migration, 16= selling household assets, 17 = Use efficient fishing gear, 18= other

802. What challenges and constraints are you facing in trying to adapt to climate change?

803. What interventions would you wish to be carried out to adapt to climate change impacts?

Study 4: Questionnaire

HOUSEHOLD LIVELIHOODS & IMPACTS OF DEVELOPMENT INITIATIVES

MODULE 1: BASIC HOUSEHOLD INFORMATION

101. Basic information

Code of the household Head		Questioner No	
Starting time		Finishing time	
Gender[1]		Village name	
Traditional Authority		Date	
Religion [2]		Interviewer	
Ethnic[3]			

[1]*Gender: Male = 1, Female = 2*

[2]*Religion: Christian =1, Muslim = 2, Traditional beliefs = 3*

[3]*Ethnic: 1= Yao, 2 = Lomwe, 3 = Ngoni, 4 = Chewa, 5 = Tonga, 6 = Tumbuka, 7 = Sena, 8= Other*

102. Family Size, age and educational status

Total Family size	Male	Female	Family relation	Age (elder to younger)	Sex M/F	Education (yrs)	Occupation[1]
***Note:*-list age from elder to younger** **-HHH= household head, wife** -use: **C1, C2, C3**…for Child 1, Child 2 etc and **others** for relatives, 2 =wife, 3= cousin, 4= nephew, 5 = aunt, 6= niece *Codes: 1=agriculture; 2= capture fisheries; 3=fish farming; 4= hunting; 5 business, 6=house wife; 7= other specify*							

103. What year did you move in this area? .....

104. Where is your place of origin? …….

MODULE 2: ASSETS AND WEALTHY

201. Does your household have the following assets? (Please read out the list)

Type of asset	**Record 1 = Yes and 2 = No**	**Number in possession**	**Year bought / Built**	**Cost**
[1]Type of House:				
Fishing nets				
Fishing vessels				
Engine for boat				
Plough/Ridger				
Radio				
Wheelbarrow				
Shovel/pick				
Treadle pump				
Bicycle				
Cell phones				
Sewing machines				
Ox-cart				
Axe				
Hoe				

Panga				
Sickle				
Motorized pump				
TV				
Mattress				
Tables				
Solar panels				
Car				
Number of structures (Granaries, Kholas etc.)				

[1]Type of house: 1 = Burnt bricks & corrugated iron sheets, 2 = Burnt bricks and grass thatched house, 3= Un burnt bricks & corrugated iron sheets, 4= Un burnt bricks and grass thatched house, 5= Mud and iron thatched, 6 = Mud and grass thatched

202. What type of land do you have for the following?

	Household land	**Size (Acres)**	**Tenure**
1	Cropland last 12 months		
2	Living land last 12 months		

Tenure: 1=own land, 2=rented land, 3=borrowed land, 4=communal land

203a. Does your household own any livestock? 1. Yes 2. No

203b. If yes, what are the changes in your livestock during last 12 months compared to now?

Type of livestock [A]	**# owned**	**Estimated value (MK)**	**Change in the last 12 months**						
			Purchased	**MK**	**Sold**	**MK**	**Reasons for sale [B]**	**Consumed/died #**	

A. 1. Ox/bull, 2. Cow/heifer, 3. Sheep, 4. Goat, 5. Donkey, 6. Horse, 7. Mule, 8. Poultry, 9. Pig, 10. Other specify.

B. 1=To buy Food, 2=To buy household requirements, 3=To buy medicine, 4=To buy fertilizer and seeds, 5=To pay school fees, 6=For pride, 7=For social activities, 8=To exchange with food, 9=Other_____

204a. Do you practice money saving? 1. Yes 2. No

204b. If yes, how much money did you save in the last 12 months? …….

MODULE 3: INCOME & COSTS

301. Are you involved in fisheries? 1. Yes 2. No. If not go to question 309a

302. Which part of fisheries does your household take part in? (*Multiple answers are allowed*)

1. Own gear and boat, 2. Own a gear, 3. Own a boat, 4. Crew member, 5. Beach Village Committee member 6. Other specify……..

303. What was the QUANTITY and VALUE of fish caught from each of the fishing gear in the last year per the three seasons?									
Type of gear	Species [A]	Quantity (Nov – April) (kg / pales, dozens)	Value sold (Nov – April) (MK)	Species [A]	Quantity (May – August) (kg / pales, dozens)	Value (May – August) (MK)	Species [A]	Quantity (Sept – October) (kg / pales, dozens)	Value (Sept – October) the project (MK)
Gill net									
Chilimira									
Beach seine net									
Ngongongo									
Mosquito net									
Fish traps									
Hand line									
Long line									

1. Utaka; 2. Kampango; 3. Nkholokolo; 4. Chisawasawa; 5. Usipa; 6. Ncheni; 7. Ndunduma; 8. Sanjika; 9. Chambo; 10. Mlamba; 11. Mbaba 12. Bombe 13. Other specify.

304. What is the value of the fish you consume per month? ……
305. What is the value of the fish you give your fishing crew per month? ……
306. What is the value of the fish you give your relatives per month? ……

307. Did you hire your fishing equipment to others during last year?			
Equipment	**How many times per month?**	**Unit price**	**Amount**
a. Engine boat (s)			
b. Net (s)			
c. Boat / Canoe (s)			

308. How much do you spend on the following per fishing trip?			
Cost structure	**Quantity**	**Unit price**	**Amount**
a. Labor (crew)			
b. Siginala			
c. Fuel (Engine boat)			
d. Food (Crew)			
e. Net licensing			
f. Net hiring			
g. Boat hiring			
h. Engine hiring			
i. Net repair			
j. Boat repair			
k. Engine repair			
l. Transport to markets			

Non - fishing income, expenditure, and savings status of the household

309a. Do you/member of your family involved in different non fishing activities?

1. Yes 2. No

309b. If yes, how much did you earn from the following non-fishing activities on average in the last 12 months?

Type of business	**Which months**	**Income per month**	**Estimated Cost incurred/month**	**Net profit/ month**	**Total income/Year**	**Average time invested/ month**	**Who participate**
a. Farming							
b. Petty trading							
c. Pottery							
d. Tannery							
e. Local brewery							
f. Blacksmith							
g. Weaving							
h. Masonry							
i. Carpentry							
j. Daily labour (Wage labour)							
k.							

310. If you are not involved in the above mentioned non-fishing activities what are the factors that inhibit you from being involved?

1. *Lack of skill, 2. Taboos, 3. Gender based division of labour, 4. Lack of initial capital, 5. Poor return to labour and capital, 6. Other (specify)…….*

311. What major crops did you grow for home consumption and sale in the last 12 months?								
Type of crop grown	A	B	C	D	E	F	G	H
	Area cultivated (A/yr)	Output (kg/yr)	Home conspn. (Kg/yr)	Sale (kg/yr)	Seed (kg/yr)	Balance (kg/yr)	Price/kg	Total income
Maize								
Cassava								
Rice								
Common beans								
Irish potato								

Sugarcane								
Cotton								
Pigeon peas								
Sweet Potato								
Sorghum								
Millet								
Other specify								

312. What are the major crop production cost you incurred in the last 12 months?

Input	**Unit of Measure**	**Quantity**	**Unit price (MK)**	**Total Cost incurred in the year 2016/2017**
Fertilizer				
Seeds				
Pesticide				
Labour (employed)				
Transport to buy inputs				
Transport costs for the harvest				
Others specify				

313. What livestock products did you sell in the last 12 months?

Livestock products/services	**Estimated Value in MK during 12 months year**				
	Produced (kg/lt./no)	**Estimated value (MK)**	**Sold**	**Consumed**	**Total**
Milk					
Butter,					
Cheese					
Eggs					
Renting income					
Other specify					
Hides and skins					
Other specify					

314a. Have you incurred any cost related to livestock management? 1. Yes 2. No

314b. If yes, what was the estimated costs on

Description of cost	**Estimated total Cost incurred during the last 12 months**
Vet service	
Fodder	
Tax (sale)	
Labor (employed)	
Others specify	

315. Do you hire your agricultural land and livestock to other village?			
Land / animals	**How many times per month /year?**	**Unit price**	**Amount**
Land			
Animals			
Oxcart			

316. How much money did you spend on food for your household during last December to March this year?

317. .During the last 12 months are there any months where your household did not have enough food? 1. Yes 2. No

318a. Do you have access to any kind of credit service? 1. Yes 2. No

318b. If yes, from where ……

319. If you have received credit this year for what purposes……

320. Have you handed out any gift (Remittances) to relatives/friends and so on during the last 12 months?
a. In cash amount…….
b. In kind estimated value of ……

321. Have you received any gift (Remittances) from relatives/friends and so on during during the last 12 months? a. In cash amount…….
b. In kind estimated value of ……

322. Do you have any forest? 1. Yes 2. No

323. Do you get any benefit out of the forest? 1. Yes 2. No

324. How often do you collect resources from the forest / woodlot per month?.....

325. Income from forest and woodlot last 12 months:

Resource	**Unit**	**Weekly collected**	**Time hours/ week**	**Consumed/week**	**Sold /week**	**Bought/week**	**Price/ unit**	**Total Income**
Charcoal								
Firewood								
Fodder								
Poles								
Bamboo								
Ropes								
Mushrooms								
Vegetables								
Honey								
Licks								
Medicine								
Grass								
Water								
Other								

326. Which of the above named resources are typically collected by:
326a: Women: ……
326b: Men: ……
326c: Kids: ……

327. Have you incurred any cost due to protected forest over last one-year? If yes, what and estimated cost incurred.

What?	Cost per year	total cost over last five year?
a) Damage to property from wildlife	…….	……
b) Fine	……	……..
c) Loss of farm land	……	……
d) Conflict with poachers	……..	
e) Others ……		

MODULE 4: DEVELOPMENT INITIATIVES & OUTPUTS

401. Below is a list of different development initiatives which were implemented in your area. Ask knowledge of the projects.

	Project Name	**How many years was the project (Years)**	**How where you chosen?**	**Where you involved to develop the project? 1. Yes 2. No**	**What was the main purpose of the project?**	**How did you benefit?**	**Did the project looked at issues of climate change? Yes 2. No**	**Are the project activities continuing after its implementation? 1. Yes 2. No**
a.								
b.								
c.								
d.								
e.								
f.								
g.								
h.								
i.								
j.								
k.								
l.								
m.								

How were you chosen?

1. Randomly 2. Beneficiaries chosen during village meetings, 3. Related to the chief, 4. Identified through Village Development Meetings 5. Others specify

Project purpose: (*Multiple answers are accepted*)

1. Fisheries, 2. Provision of processing facilities, 3. Fish catches enhancement, 4. Provision of better fishing gears, 5. Provision of better fishing and 6. Provision of affordable vessels, 7. Women participation in fisheries, 8. Ecosystem management, 9. Provision of fishing gears and vessels on credit, 10. NRM 11. Forest Mgt, 12. Soil fertility mgt, 13. Promoting climate change technologies 14. Road maintenances, 16. Electrification, 15. Forestry management 16. Improvement of food security 17.Crop subsidy 18. Animal improvement 19.

PART TWO: Compilation of Papers

Paper I

Limuwa, M. M., Sitaula, B. K., Njaya, F. & Storebakken, T. (2018). Evaluation of Small-Scale Fishers' Perceptions on Climate Change and their coping strategies: Insights from Lake Malawi. *Climate*, 6 (34): 1-23.

climate

MDPI

Article

Evaluation of Small-Scale Fishers' Perceptions on Climate Change and Their Coping Strategies: Insights from Lake Malawi

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Abstract: The effects of climate change have negatively affected Malawi's agricultural production. In this context, fisheries have been providing alternative livelihoods. However, there is a knowledge gap around the responses of small-scale fishers to climate-related changes. Therefore, a study was conducted on the Western shores of Lake Malawi between August 2015 and April 2016. The study evaluated the perceived effects of climate change on small-scale fishers and their coping strategies by employing a wide range of methods for data collection and analysis. The study used explorative surveys, household surveys, focus group discussions and key informant interviews to collect data. The study randomly sampled 112 household heads who owned either fishing gear or a fishing vessel or both. Content analysis for themes was used to analyse the qualitative data. The Mann–Kendal Test was used to analyse trends in meteorological data, and binary logistic regression was used to determine factors that influence coping with low fish catches. Despite the respondents noticing an increased incidence of extreme weather events and low fish catches, their perceptions could not be validated using time series meteorological data. However, such perceptions were influenced by experience from long-time exposure to extreme weather events and to low fish catches. The majority of the fishers had adjusted to these changes by increasing their fishing time, using highly efficient illegal fishing nets, expanding farming land, operating small businesses and undertaking casual labour in agriculture and fishing activities. The fishers' propensity to adjust to these changes increased due to the presence of the following factors: older age of household head, higher education level, being married and having an annual income. In contrast, being a member of fish conservation club decreased the probability of adjusting. This study emphasizes the need to be cautious when defining and framing perceptions of local communities on extreme weather events as data obtained could be misleading. Furthermore, a multi-sectoral approach to balance sustainable livelihoods and management of fisheries is needed. These findings provide theoretical and practical lessons that can inform design, planning and implementation of policies that enhance adaptive capacity in fisheries and promote sustainable livelihoods in sub-Saharan Africa.

Keywords: perceptions; Lake Malawi; climate change; coping strategies; logistic regression; vulnerability; adaptive capacity

1. Introduction

Global food production systems have been impacted by climate change [1]. This problem is increased because the adaptive capacity of many poor communities is too low to enable them to be resilient. This is a picture which commonly describe many developing countries whose people are poor and vulnerable [2]. One such country in the Southern part of Africa is Malawi, which has been facing increased impacts of extreme weather events more frequently in the last decades than ever before [3].

These extreme weather events have affected Malawi's agriculture sector on which its development agenda is framed [4]. This is because Malawi's agriculture heavily depends on rainfall [5]. This makes Malawi's economy and its people more vulnerable; thus, they continue to search for other sustainable livelihood sources. Malawi fisheries have, for a long time, cushioned the impacts of low agricultural productivity [6,7].

Small-scale fisheries support the livelihoods of over 180 million people in developing countries; Malawi's fisheries support its entire population [8–10]. In this case, the small-scale fishers are important because they produce more than 90% of Malawi's total annual fish catches. Although fish has remained the cheapest source of animal protein for many rural Malawians [10], the edible fish population has also been fluctuating [10,11] leading to collapse of some important fisheries, like Lake Malombe [12].

The decline in the fish population has been attributed, among other factors, to overfishing [13–15], weak governance structures and environment-related changes [16]. Although it has been difficult to ascertain whether climate change could be among the factors affecting Malawi's fisheries specifically, at a global level, climate change has been reducing fish catches [17–21].

This should be a major concern to Malawi fisheries, as climate projections, under different scenarios, indicate higher maximum temperatures and lower annual precipitation levels than previously experienced [22–27]. These projected changes will have a direct influence on Malawi fisheries via an increase in water temperature and a decrease in fish production in water bodies like Lake Malawi [28,29]. Increase in water temperature lowers water mixing which bring food for fish from the bottom of the lake [30,31]. However, there is still a lack of knowledge on the influence of such effects on Malawi fishers' livelihoods and coping strategies.

Attempts have been made to investigate such impacts at Lake Chilwa in Malawi [32,33]. However, the knowledge gained was specific to that ecosystem and cannot be applied or generalized to other ecosystems like Lake Malawi. This is because the contexts of the communities along these two water bodies are different. Therefore, using such knowledge to create local policies that enhance sustainable livelihoods will not meet the intended goals [34].

If sustainable livelihoods are to be achieved, there is need to mainstream adaptation into development policies [35]. Implementation of such policies might strengthen the adaptive capacity of small-scale fishers. Adaptation is a difficult process when coupled with a declining fish population [36]; however, understanding the local context might provide solutions to enhance adaptation.

It is paramount to understand local conditions to improve the potential for policies to be correctly designed and to increase chances that they will actually be effective in promoting climate adaptation. Therefore, we explored the perceptions of Lake Malawi's small-scale fishers on climate change and its effects on their livelihoods using the following research questions: (a) What are the perceptions of the fishers on climate change and what influences such insights? (b) What are the effects of these perceived changes on fish catches? (c) What are the fishers' coping strategies to the perceived changes? (d) What factors determine these coping strategies?

2. Conceptual Framework

This study was framed around the vulnerability [37] and perception [38] conceptual frameworks. The vulnerability framework has its basis in the Intergovernmental Panel on Climate Change (IPCC)'s Third Assessment Report (TAR) [39], whereas the perception framework was developed for drought studies in the Ogallala Aquifer in the Western United States Great Plains. These two frameworks have

been applied in many climate-related studies [40–43], and in this study, it enabled the application of mixed research methods to assess the vulnerability level of Malawi small-scale fishers using perceptions as a basis to access their impacts on climate change. The combination of these two frameworks (Figure 1) was used to show how fishers view climate change and at the same time, gave a comprehensive platform to capture features of complex systems, such as fisheries [44]. Furthermore, these two concepts are imaginative in nature and offer a method of assessing the relationships between the human and environmental systems.

The vulnerability framework has weaknesses in that it does not consider the mental processes that drives individuals to change their behaviour when exposed to climate changes. Moreover, it assumes that time is irrelevant [40]. These weaknesses were overcome by incorporating the perception framework, which focuses on behaviour, values, beliefs, knowledge and culture [38].

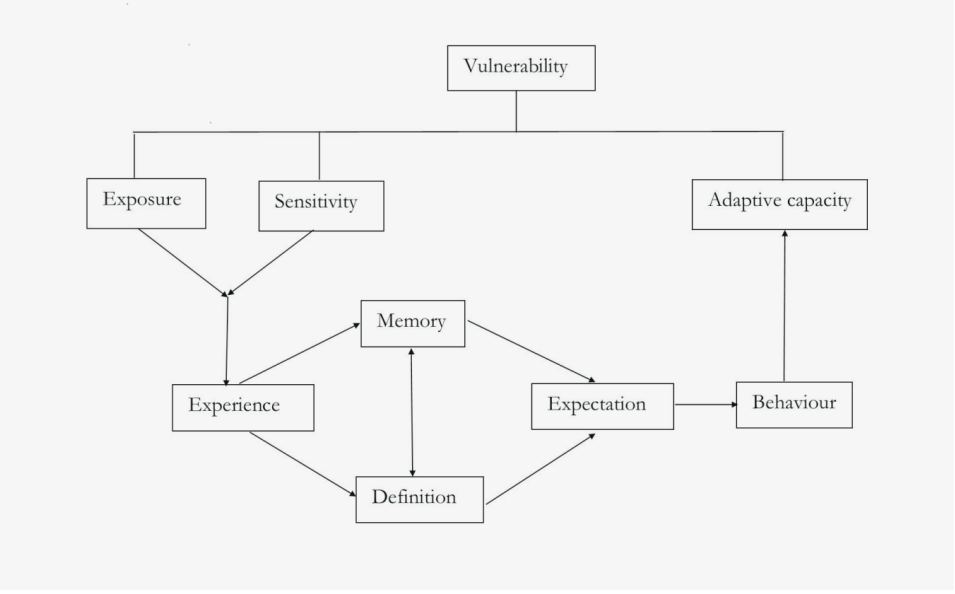

Figure 1. Vulnerability—perception conceptual framework (adapted from [38,39]).

The perception framework is hinged around psychology, which is study of behaviour and mental processes [45]. Furthermore, psychology is closely linked with perceptions [46]. However, perceptions are subjective [47] and comprise a wide range of things which are contextual, value-laden and dynamic [38,47]. For example, a definition of a similar event might be different within a group of individuals in the same environment [48], due to social constructs [47]. Perceptions are also associated with experience, i.e., how individuals react to situations [38]. This is so because perception is a function of the actions displayed thereafter [49]. The experience component is the link to the vulnerability framework through the exposure and sensitivity components.

In addition to exposure and sensitivity, the other component of the vulnerability framework is adaptive capacity. Exposure is the nature to which a system is exposed to significant climatic variation, while sensitivity is the degree to which a system is affected either adversely or beneficially by climate-related stimuli [39]. Adaptive capacity is the ability of a system to adjust to changes [37]. Exposure, sensitivity and adaptive capacities vary across temporal and spatial scales [50], making findings from other fisheries difficult to generalise. Many studies that have theorized vulnerability

have found it to be influenced by socioeconomic, cultural, political and technological factors as well as access to financial resources, kinship networks and environmental conditions [37,50,51].

On the other hand, many climate change-related studies have used the perception concept as a tool to understand how people interact with their environment [52–63], but many of them have failed to look at how perceptions are theorized.

Failure to theorize the findings could also be equated with failure to declare how vulnerability is framed. Therefore, in using the vulnerability framework, we followed the human security framework [64], because it links fishers' inability to cope with low fish catches as being due to many stressors, which includes climate. We applied the vulnerability framework based on the contextual issues affecting the fishers.

Linking these two frameworks enabled the study to relate how exposure and sensitivity to past events has been shaped and defined. In our case, fishers remembered events they were exposed to, and this had a bearing on expectations of similar future events, which affected their behaviour [38]. The act of remembering is a psychological aspect of their memory and has a time factor attached to it. The outcome of such behaviour could either be reactive or proactive [ibid]. The displayed behaviour could also be associated with whether a fisher copes with, adapts to, or continues their fishing behaviour because of being satisfied with their fish catch. Behaviour is responsible for the process of choosing either short-term goals, which in most cases are unsustainable (for example, overfishing or using non-selective fishing gear which is destructive), or long-term sustainable goals.

However, in using the composite framework, we made assumptions based on Malawi's projected temperature and precipitation levels [25,65]. The climate-related impacts based on such projections might potentially affect the provision of ecosystem services from the fisheries on which many people base their livelihoods. If fishers are vulnerable to such changes, what could be factors driving them to perceive the situation in that manner? Moreover perceptions to extreme weather events were validated with the use of meteorological data [58,66].

3. Study Area

The study was conducted in Nkhotakota district between Geographical Positioning System (GPS) Coordinates −13°35′09″ S, 34°29′ 90″ E and −12°62′73″ S, 34°17′46″ E, along the Western shores of Lake Malawi in the central region of Malawi (Figure 2). Lake Malawi is also situated alongside two other countries (Mozambique and Tanzania). Lake Malawi has about 500–1000 endemic fish species [67], and Nkhotakota district is one of the five-lakeshore districts on the Malawi side.

Nkhotakota has a population of 303,659 people representing 2.3% of Malawi's population. The proportions of men and women in Nkhotakota are equal [68]. The climate of Nkhotakota has been variable [29]. Its average annual rainfall ranges between 860 and 1600 mm between December and March, whereas, its monthly average temperature ranges between 20 and 28.7 degrees Celsius. Nkhotakota district has an approximate area of 7500 km^2, of which 43% of it is under water [69].

Although 57% of Nkhotakota is covered by land, only a small portion (6%) of it is left for its people to use for shelter and agriculture. Large chunks of land are divided between commercial sugarcane plantation and protected game and forest reserves. The people of Nkhotakota are mainly engaged in growing cotton, burley tobacco, cassava and rice, while maize is grown on a small scale. Rice, cotton and tobacco are mostly grown for sale with maize and cassava for food. Nkhotakota is highly vulnerable to extreme weather events [69,70], making food production from agriculture a big challenge.

Vulnerability to agriculture drives many people in Nkhotakota to focus on fishing. Nkhotakota's fishing gear owners represent 18% of the total proportion of owners on Lake Malawi, and of these, about 2% are women. Crew members from Nkhotakota represent 17% of the entire Lake Malawi fishing population [71]. Nkhotakota fishery industry is characterized by multiple species and multiple types of gear [72]. Despite the majority of Nkhotakota's population being small-scale fishers [69,71], there is lack of information on these fishers' vulnerability to changes related to climate.

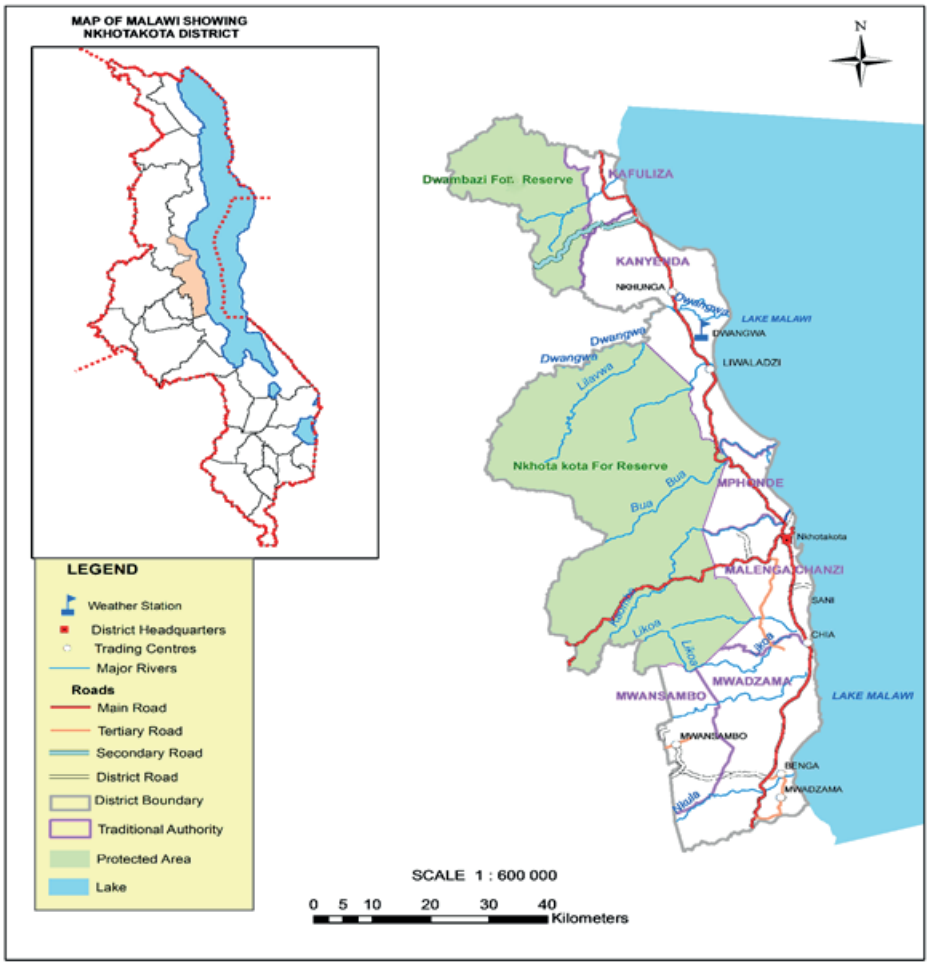

Figure 2. Map of Malawi showing Nkhotakota district and the study area.

4. Methods

4.1. Data Collection

The study used mixed research methods to collect information from the respondents [73,74]. Nine exploratory interviews at different fish landing sites within the study area were conducted between August 2015 and December 2015. These interviews targeted local fishery conservation groups, village management structures, fishers and fish traders. The sample comprised both men and women in order to capture a variety of perceptions [60]. These interviews contextualized the study by asking the respondents to describe their local climate and any changes associated with climate occurring in their area. In addition, the respondents were asked about fish catches and any changes that had occurred and the reasons as to why such changes were happening. The respondents were also asked to cite how they were coping with such changes. The responses to the interviews identified the perceptions of the local people [47] and helped to frame quantitative surveys as a follow up to the critical issues gathered during the exploratory surveys.

After the explorative interviews, semi-structured questionnaires (Supplementary File S1) and checklists were developed, pretested and validated [75,76]. The questionnaires captured both quantitative and qualitative information from household surveys [77]. Checklists were used to collect information from focus group discussions and key informant interviews. Some of the aspects covered in the questionnaire included household characteristics and composition, household fishing data, household sources of income, climate change risks, perceptions of climate and ecosystem changes and an analysis of climate change coping measures. The questions avoided leading answers on climate scenarios, but they were open-ended to allow the fishers to discuss and elaborate more on their perceptions [66]. Data collection took high ethical principles into consideration [78]. The household surveys, focus group discussions and key informant interviews were conducted between February 2016 and April 2016.

The survey was administered to 112 fisher household heads (98% male and 2% female) randomly sampled [79] from five fish landing sites (Mwadzama, Chipala, Vinthenga, Kamguzila and Luwaladzi). In addition to the household survey, ten focus group discussions, comprising an average of twenty members per group, were conducted to further probe issues, which emanated from the exploratory interviews and household surveys. The focus group discussions were coordinated by a single moderator in order to maintain consistency in question delivery, timing emphasis and reactivity potential [80]. In establishing focus group discussions, age, gender and the nature of work in the village were considered [60]. Furthermore, five key informant interviews with chiefs, local fishery conservation group members and fish traders were conducted using a phenomenological research approach [81] in which their lived experiences were probed. The use of these methods triangulated different sources of information in order to improve validity [80,82].

To further validate fishers' perceptions, secondary data sources on meteorology (temperatures, rainy days and precipitation) were used [83,84]. Climate data from the previous 34 years (1982–2016) was obtained from a nearby weather station at Illovo Sugar Company, Dwangwa Estate, located at Geographical Positioning System (GPS) coordinates −12°31′06″ S, 34°07′55″ E.

4.2. Data Analysis

Qualitative data from exploratory surveys, focus group discussions and key informant interviews were transcribed, translated into English and analysed using content analysis for related themes [85]. The analysis involved coding to generate initial themes, searching for themes among the codes, and reviewing and naming the themes [86]. The identification of related themes was based on recorded patterns within the data. Themes were related to specific research questions and they also guided further data analysis. In order to support and clarify the perceptions of different respondents interviewed, direct quotations were also used.

Household survey data from the sampled respondents were analysed using descriptive statistics (means, ranges, frequencies and percentages) [87]. Descriptive statistics were used to identify the main characteristics of the participants. On the other hand, inferential statistics were used to assess whether relationships existed between certain respondent characteristics and the fishing environment. For example, cross tabulations (non-parametric test) were used to determine the associations between (a) a fisher's main occupation and income source and (b) the fisher's perceived climate change exposure and changes in fish catches and (c) coping strategies and type of climate exposure [88]. Another inferential statistic used was the Pearson's correlation coefficient, which determined whether any relationship existed between the maximum annual temperature and total annual precipitation. Furthermore, the Mann–Kendall (MK) test [89,90] was used to establish the presence of trends in precipitation and temperature of the meteorological time series data [91]. In order to verify if the required conditions for the MK test were met, one of the assumptions was to check if there was any random correlation between the variables being tested. Therefore, serial correlation was checked in the precipitation and temperature data using a pre-whitening procedure prior to conducting the MK tests [92]. The influence of serial correlation may lead to committing a Type 1 error [93], that is rejecting

the null hypothesis when it is, in fact, true. The annual precipitation and temperature anomalies were standardized, i.e., departures from the mean divided by the standard deviation, were compared with the fishers' perceptions [84,94].

Finally, a binary logistic regression was used to determine factors which affected fishers' coping behaviour with the perceived fish catch changes [95]. These factors were gathered through the household survey and were assessed using bivariate correlations prior to running the logistic regression. Of these factors, annual income was log transformed to remove skewness before running the logistic regression so that it conformed with the regression assumption of normality [96]. In conducting descriptive and inferential statistical procedures, Microsoft Excel, Statistical Package for Social Scientists (SPSS) version 24 and Stata version 14.2 were used.

5. Results

5.1. Characteristics of Fishers

The results from this study showed that fishing (90%), farming (6%) and operating small businesses (4%) were the main livelihood sources. The fishers' main occupation and sources of income were significantly different ($\chi^2 = 16.55$, $df = 6$, $p < 0.01$). The majority (65%) of the respondents stated that they consume fish every day. More than 90% of the respondents access drinking water from the lake, and a small proportion (1%) access their drinking water from a public utility company. These results suggest the importance of Lake Malawi to the livelihoods of its surrounding communities.

The study also categorized fishers in the study area based on fishing vessel types, fishing location and fishing gear types. We observed that 22% of the fishers use boats with outboard engines, while 44% have boats without engines and a small proportion (26%) use dugout canoes. The majority (76%) of the fishers operate in the offshore waters, whereas 24% fish the inshore waters. The fishers take an average of 2 h to reach the fishing ground. Half of these fishers (50%) spend 3 to 6 h fishing, compared to the other half that spend 9 to 10 h. However, during the focus group discussions, we observed that there have been changes in the time spent fishing. *Beach Village Committee #1, 15 December 2015* "*We travel very far away in search of fish than in the past.*" These results could be a reflection as to why the majority of fishers fish in the offshore waters. Gillnets (60%) whose average length is 917 m were the most common fishing gear type in the study area. A gillnet is a rectangular fishing gear made from 4 or 6 ply twine, and has a mesh size designed to catch fish of a specific size range. It is used with a single planked boat (with or without engine) and a crew of four. The net may be surface set or bottom set and is a passive gear [97]. The gill nets are used to catch Copadichromis virginalis, *Bagrus meridionalis*, *Mylochromis guentheri*, *Rhamphochromis spp.*, *Synodontis njassae*, *Tramitichromis intermedius*, *Opsaridium microcephalum* and *Oreochromis species*. The other group of fishers (35%) use open water seine nets whose average length is 107 m. An open water seine net has a conical appearance and is used at night to catch *Engraulicypris spp.*, while during the day, the gear is used to target *Copadichromis spp*. The net is towed in the opposite direction to the movement of the fish and finally hauled into the plank boat [98]. Open water seine nets are used to catch *Engraulicypris sardella*, C. virginalis and *T. intermedius*. Some fishers (3%) use fish traps to catch C. virginalis and *O. microcephalum*, whereas longlines (2%) are used to catch *B. meridionalis*. The study further noted that some fishers (58%) use nets with mesh sizes ranging from 0.25 to 1.75 inches while the other category (42%) use mesh sizes of 2.5 to 3.5 inches. It was reported by key informant # 1 regarding the question of what has changed in their fishing behaviour that "*Almost everyone in this fishing area has adjusted their fishing equipment. Ten years ago, I used to operate gillnets with mesh sizes of four and half (4.5) inches and I was catching many fish. As it is now, I cannot use such type of nets because I will not catch anything, and my family will die of hunger*". Despite the small mesh sized fishing gears, which have improved fishing efficiency, the study also, revealed a high diversity of fish species being caught.

5.2. Fishers' Perceptions on Changes in the Climate

Even though the study revealed high species diversity, all fishers interviewed acknowledged been exposed to extreme weather events. The fishers reported increased incidences of drought (32%), erratic rainfall (32%), extreme hot temperatures (22%), persistent Mwera winds (strong South easterly winds affecting Lake Malawi due to the flat and obstruction-free nature of its surface, allowing winds of considerable strength to develop. The onset of a Mwera can be quite sudden, causing rapid deterioration in the condition of the lake itself) (11%) and flooding (8%). Most of these fishers (88%) revealed experiencing these extreme weather events in the 21st century. These events occurred frequently in the years between 2000 and 2016, as reported by 89% of the fishers. The majority of the fishers (90%) acknowledged experiencing continuous drought incidences. However, in the last 5 years, about half (44%) of the respondents cited no flooding event in the study area. Apart from being erratic, rainfall was also reported to have reduced in intensity (94%). The reduced intensity might have resulted in drier years in the 2000s, as cited by most respondents (95%), in comparison to the 1990s. These results suggest that the perceived exposures revolved around precipitation and temperature.

An analysis of discussions from qualitative interviews revealed that climate change is defined differently between respondents. The definitions were affected by the time lived in the area, which affected how the fishers perceived the changes. For example, there were variabilities in responses by different age groups based on the way they had experienced different changes related to extreme weather events. The older people recollected past events over a long period through experiences and oral tradition, whereas the young fishers lacked the long-lived experiences but their recollections were also based on information passed down to them through oral tradition. Most of the oral tradition was bound by cultural beliefs as alluded to by one fisher, aged 67 years old, during a focus group discussion:

" . . . . . In the past with such frequent occurrence of droughts, the elders of the clan would go and seek advice from the medium spirits and God. Droughts and floods were a form of punishment of some sort, but currently things have changed and believing in medium spirits was outdated, it is all about churches and praying to God . . . . . "

This experience has an effect on how the extreme events are defined, with the older individuals saying such events are normal but that the sensitivity of occurrences has increased. This is so because they have a reference point from their past. This was not the case for the young fishers, who claimed that these changes are not normal. Therefore, the frequent occurrences of these extreme events has made these fishers more vulnerable than in the past.

An example was also given for the lake level changes, as an indication of lower precipitation and extremely hot temperatures. The respondents cited that the place where we were conducting our interviews, which was 50–100 m from the shoreline, used to be underwater, but over the last 20–30 years, it has become dry land. In addition, some fishers have built houses in that area.

" . . . .If it was not for the drying of the lake we would not have a place to build our houses because we migrated to this area as fishers and getting land to settle as migrant fishers, is very difficult . . . ."

On the other hand, during a key informant interview with a male fisher on 15 November 2015, he reported *"By now 30 years ago, we should have planted crops and the rains would have been falling with good intensity. Currently, it is very hot and dry and people are not even sure as to when the rains will fall"*.

5.3. Analysis of Meteorological Data

5.3.1. Precipitation

Contrary to the perceptions of the fishers, the results from the meteorological time series data showed that between 1982 and 2016, most of the annual precipitation (96%) fell between November and April which is the normal rainy season, while 3% fell between May and August and 1% fell between September and October. The Mann–Kendall (MK) trend test results showed a decrease in precipitation in the study area over time (Figure 3). These results were only statistically significant

(*Mann–Kendall (s)* = −127 ($p < 0.05$) for the cool-dry winter season (May–August) which might illustrate interseasonal variability in annual precipitation.

The precipitation varied between 1982 and 2016, with the lowest (745 mm) and highest (2161 mm) values recorded in 2005 and 1989, respectively. The annual precipitation for the main rainy season (November–April) decreased by 6 mm per year compared to the total annual precipitation which also decreased by 4 mm per year between 1982 and 2016 (34 years). Despite the decreased precipitation rates between 1982 and 2016, there was an increase in the total annual precipitation (14 mm) for the warm-wet season (17 mm) between 1982 and 2002 (20 years). Although a large proportion of the fishers (>90%) reported decreased precipitation in the last 20 years, the results from the long time series of precipitation showed variable annual rates between the years.

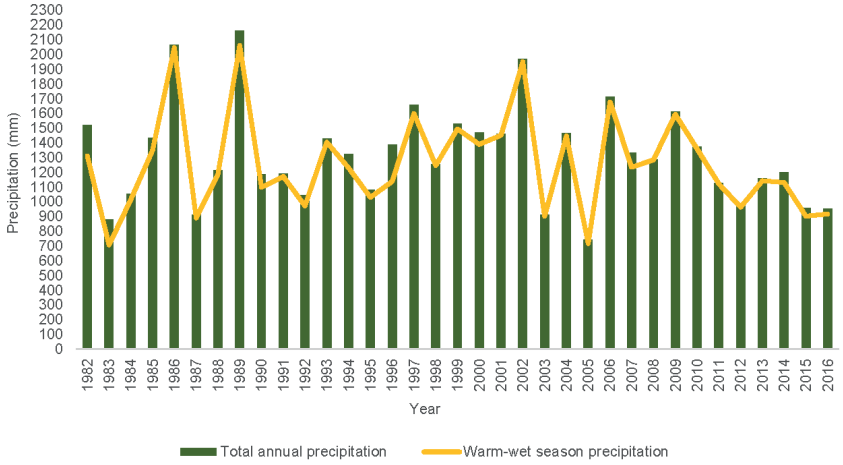

Figure 3. Mean total annual and warm-wet season precipitation (mm) for Dwangwa, Nkhotakota, Malawi from 1982–2016.

The study further showed that the average number rainy days had decreased by 0.7 per year. The highest total number of rainy days (180 days) was recorded in 2000/2001, while the number of average rainy days for the 34-year period was 97 days. The precipitation anomaly for the study area (Figure 4) showed both negative and positive trends, reflecting variable precipitation.

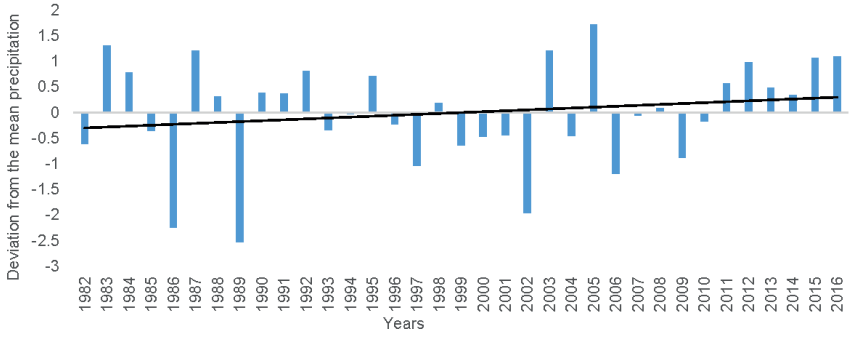

Figure 4. Annual precipitation anomalies for Dwangwa-Nkhotakota weather station from 1982 to 2016.

5.3.2. Temperature

Some fishers (22%) perceived extremely hot temperatures, and the Mann–Kendall (MK) trend test also showed an increased maximum annual temperature by 0.007 °C and a decreased minimum annual temperature by 0.001 °C per year (Figure 5). However, the temperature results were not statistically significant ($p > 0.05$). The highest (29.7 °C) and lowest (28.4 °C) mean annual maximum temperatures were recorded in 2005, and 1985 and 1989, respectively. The highest temperature in 2005 coincided with lowest level of precipitation (745 mm) and there was a statistically significantly relationship between the two ($r = -0.611$, $p < 0.01$). This suggests that the high temperatures experienced by the respondents might have been due to increased rates of evapotranspiration.

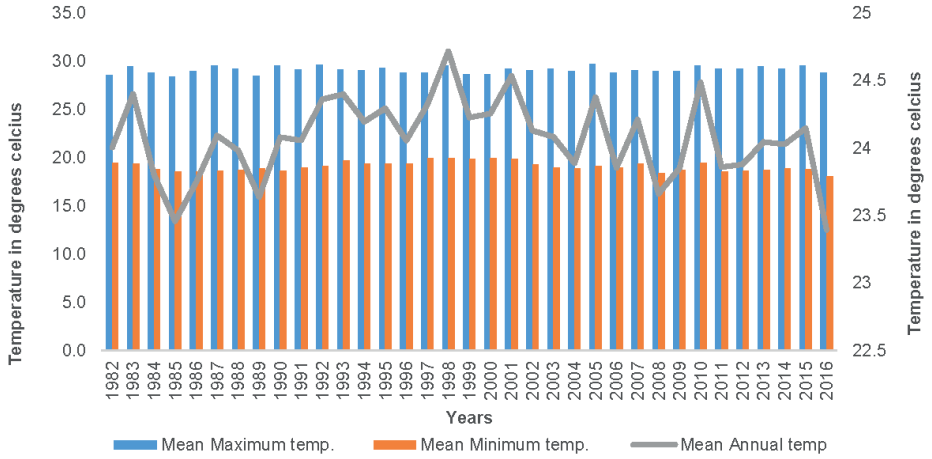

Figure 5. Mean annual maximum, mean annual minimum and mean temperatures for Dwangwa, Nkhotakota, Malawi in 1982–2016.

The anomalies for maximum and minimum annual temperatures between 1982 and 2016 showed no defined trend (Figure 6). These results might be a reflection of a non-stable cooling or warming pattern in the study area.

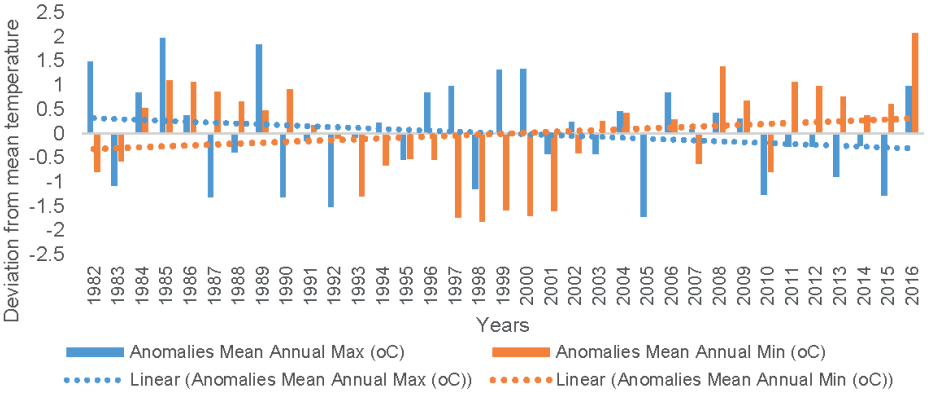

Figure 6. Annual maximum and minimum temperature anomalies for Dwangwa, Nkhotakota, Malawi in 1982–2016.

5.4. Impact of the Perceived Climatic Changes on Fish Catches

Despite no significant trends in the meteorological data, there was significant association between the fishers' perceptions on the changes in climate and fish catches ($\chi^2 = 44.02$, $df = 20$, $p < 0.001$). The majority of the fishers (89%) reported that the change in climate was the main driver of low fish catches and species composition changes. However, some fishers (10%) attributed low fish catches to overfishing and God's plan (1%). The specific extreme weather events cited by the respondents as being responsible for low fish catches were increased incidences of drought (29%), erratic rainfall (29%), Mwera winds (27%), extreme hot temperatures (11%) and flooding (5%).

The majority (68%) of the fishers were experiencing changes in fish species composition and sizes compared to last 20 years. For example, some fishers reported that C. virginalis (31%), *E. sardella* (26%) and *Oreochromis species* (20%) used to be more important fish species in Nkhotakota 20 years ago compared to their present status.

An analysis of qualitative material revealed the existence of variations in reasons why the fishers were experiencing low fish catches and fish species composition changes. For example, during the qualitative interviews, some fishers cited the following reason: "*..the fish have gone to the Mozambique side of the lake, running away from fishing pressure . . . ..*"

Some respondents who had indigenous knowledge on the relationship between climate and fish catches explained how rainfall is related to fish catches, with more rainfall resulting into more fish catches. Furthermore, they explained that high temperatures also reduce Mwera winds, and more fish are caught because fishers are not hindered from fishing, because Mwera winds increase the risk of operating fishing boats.

The older respondents cited population increase as causing low fish catches, because too many fishers are fighting for too few fish. Therefore, fishers use illegal fishing gears because they have to survive. On responding to the question on the change of behaviour in fishing practice, the focus group discussions stated that not much is happening in the agricultural fields and many people are joining the fishing industry in order to survive.

The study showed that there were some disparities between quantitative and qualitative results. The quantitative output seemed to point to climate change as the major cause for low fish catches, whereas the same climate seemed to increase fish catches based on the qualitative analysis. Therefore, it is difficult to entirely validate such perceptions without a long-term assessment of climate and fish stocks.

5.5. Coping Strategies for Low Fish Catches and Determining Factors

The study showed that the majority (75%) of fishers had adjusted to other livelihood patterns in order to supplement fishing. The adjustment strategies included expanding their agricultural farming land, operating small businesses (small retail shops, buying and selling fish and farm produce) and providing labour services to agriculture and fisheries (Table 1). However, some fishers (25%) did not adjust to the perceived changes as they accepted the low fish catches.

Table 1. Nkhotakota fishers' ($n = 112$) coping strategies to low fish catches matched with their perceived climate exposure.

	Agriculture	Business	Labour in Agriculture	Labour in Fisheries	No Strategy
Extremely hot temperatures (%)	15	53	14	20	18
Incidences of flooding (%)	3	0	0	0	11
Persistent Mwera winds (%)	10	13	21	20	14
Erratic rainfall (%)	45	13	29	33	25
Increased drought incidences (%)	28	20	36	27	32
Total number of respondents (*n*)	**40**	**15**	**14**	**15**	**28**

Source: Fishers' perceptions survey data, 2016.

Although some respondents did not adjust their livelihoods, most respondents (84%) had access to weather information, which guided them in terms of where and when to fish. The sources of information

were diverse, with the majority (83%) accessing information through local radio stations and to a lesser extent, from churches/mosques (2%) and extension workers (1%). Despite some of the respondents getting the information from their churches/mosques, some respondents (77%) indicated that religious institutions had nothing in their teachings on climate change. Therefore, all respondents emphasized the need for the religious institutions to incorporate climate change into their teachings, in order to enhance the process of coping with the extreme weather events.

However, in the focus groups, we tried to follow up why these fishers had agriculture as a diversifying strategy, despite complaining about continued droughts. We also questioned how and why these fishers were engaged in providing casual labour in fisheries as a livelihood diversification strategy while they were complaining of low fish catches.

The respondents highlighted that relying on fishing alone is not enough, but sometimes they join other fishers' boats as crew members as a way of diversifying income. They also hire out their fishing equipment while they concentrate on other income-generating activities like farming and providing labour in agriculture. On the other hand, their involvement in agriculture is related to winter cropping which uses residue moisture from the erratic rainfall, which does not fall during the main agricultural season.

The study also analysed factors, which influence fishers' coping behaviour. The choice of the explanatory variables (Table 2) was based on available data and the current scientific literature [99–102]. Prior to conducting the logistic regression to determine which factors influence coping behavior, the relationships between the explanatory variables were assessed using bivariate correlations. The results of the correlations (Supplementary File S2) indicated significant relationships between some of the explanatory variables (age, sex, length of stay in the area, family size, fishing experience, fishing location, access to weather information, extreme temperature incidences, Mwera wind incidences, drought incidences and erratic rainfall incidences). For example, the age of the household head was positively correlated with the length of stay in the area, number of family dependents and experience in fishing. Such results suggest that an increase in age of the household head increases time stayed in the area and the fishing experience.

Table 2. Description of explanatory variables for the determinants of coping strategies for Nkhotakota fishers (n = 112).

Explanatory Variable	Mean	Std. Deviation	Description
Household head sex	0.98	0.13	Dummy takes value of 1 if male and 0 otherwise
Household head age	43.7	11.4	Continuous
Household head education	4.58	3.53	Continuous
Household head marital status	0.90	0.30	Dummy takes value of 1 if married and 0 otherwise
Time stayed in the area by HHH	33.00	15.62	Continuous
Household size	6.0	3.40	Continuous
Household head fishing experience	21.46	11.8	Continuous
Fishing location	0.24	0.43	Dummy takes value of 1 if inshore and 0 otherwise
Membership to fish conservation club	0.37	0.48	Dummy takes value of 1 if a member and 0 otherwise
Income earned last year	5.3	1.02	Continuous—Log transformed
Access to weather information	0.84	0.37	Dummy takes value of 1 if have access and 0 otherwise
Access to other natural resources	0.36	0.48	Dummy takes value of 1 if have access and 0 otherwise
Extreme weather event (droughts)	0.29	0.45	Dummy takes value of 1 if extreme weather event is drought and 0 otherwise
Extreme weather event (floods)	0.03	0.16	Dummy takes value of 1 if extreme weather event is floods and 0 otherwise
Extreme weather event (extreme temperature)	0.21	0.41	Dummy takes value of 1 if extreme weather event is extreme temperature and 0 otherwise
Extreme weather event (erratic rain)	0.32	0.47	Dummy takes value of 1 if extreme weather event is erratic rains and 0 otherwise
Extreme weather event (Mwera winds)	0.14	0.35	Dummy takes value of 1 if extreme weather event is Mwera winds and 0 otherwise

Source: Fishers' perceptions survey data, 2016 Notes: HHH is household head.

A logistic regression was then conducted to ascertain the effects of socioeconomics factors and incidences of extreme weather events on the probability that the fishers will cope with fish catch fluctuations. The estimated coefficients of the logistic regression are presented in Table 3 along with the levels of significance, standard errors and odds ratios (Exp (B)). The logistic regression model was statistically significant, $\chi^2 = 9.15$, $df = 8$, $p < 0.001$. The independent variables had adequate power to explain 52% (Nagelkerke R^2) of the variation in coping with changes and correctly classified 85% of cases. These results suggest that the model developed may be used to determine the probability that a fisher will cope with changes related to fish catch.

Several factors which include the household head's age, education, marital status, annual income and membership to a fish conversation club significantly influenced the ability to cope with fish catch changes. These factors were also statistically significantly different between the respondents who adjusted and those who did not.

The age of the household head ($p < 0.01$) and level of education ($p < 0.1$) were statistically significant with a positive coefficient suggesting an increase in age and education by one year, increased the probability of adjusting by a factor of 1.1, compared to those who did not adjust. While being married increased the propensity to adjust by almost 7-fold compared to single fishers. An increase in a unit of annual income increased the probability of adjusting by 2-fold. On the other hand, being a member of the fish conservation club reduced the propensity to adjust. These results reflect that the coping process was not homogeneous and was multidimensional.

Table 3. Binary logistic regression analysis results of factors influencing Nkhotakota fishers' (n = 108) ability to cope with perceived fish catch changes.

Explanatory Variables	Coefficients	Standard Error	Exp (B)
Household head sex	−18.76	27 933	0.00
Age of household head	0.12 ***	0.04	1.12
Household head education	0.16 *	0.10	1.18
Household head marital status	1.92 **	0.96	6.85
Length stayed by household head in the area	−0.03	0.02	0.98
Household size	0.07	0.10	1.07
Fishing experience	−0.03	0.03	0.98
Fishing location	−0.26	0.70	0.77
Membership to fish conservation club	−1.79 ***	0.65	0.17
Annual fishing income	0.73 **	0.36	2.08
Access to other weather related information	0.12	0.87	1.13
Access to other natural resources	−0.74	0.67	0.48
Increased drought incidences	−1.39	1.83	0.25
Increased flooding incidences	−23.10	21 127	0.00
Increased extreme temperatures incidences	−1.13	2.00	0.32
Increased incidences of erratic rainfall	−1.01	1.80	0.37
Increased incidences of Mwera winds	−0.87	1.94	0.42
Constant	17.36 ***	21 127	

Source: Fishers' perceptions survey data, 2016. Notes: n = 112. For binary variables (coping), no = 0 and yes = 1. *, **, and *** indicate significant coefficients at significance levels of 0.10, 0.05, and 0.01, respectively.

In the qualitative analysis, it was observed that some of the factors that were shown to significantly affect coping behaviour are similar to those in the regression model. These factors included household income, age and education and these opened room for more coping options.

6. Discussion

6.1. Fishers' Perceptions on Climate and Changes in Climate Variables

The respondents' perceptions to extreme weather events could be attributed to their levels of exposure and experience [56,103,104]. The 20-year recall period used in this study was sufficient to

validate the stated adverse weather events. The average age and fishing experience of the respondents provided sufficient platform to avoid perceptive reasoning challenges, which arise when trends are interpreted from a few recent events [46]. Age and fishing experience could be responsible for increasing the probability of recalling major climate incidences [105,106]. However, perception memories are reconstructions of forgoing schemes of clear pictures of how the world is viewed [47]. This means that what the fishers perceive to be climate change is not straightforward [107], and that is why time series meteorological data were used to validate such connections.

There were disparities between the perceptions of the fishers and the meteorological data. These disparities could be attributed to the ease of accurately describing changes over shorter periods of time compared to longer periods [108]. The majority of the respondents were fishers and farmers; therefore, they might have defined the climate to be abnormal as long it did not fit their agriculture calendar or resulted in low crop yields or low fish catches [43,46,66,109]. Therefore, memories related to livelihood failures might have been labelled as significant climate changes because knowledge obtained through direct perceptions is practical in nature and is based on what an environment offers for the fulfilment of the action in which the fishers were engaged in at the time [47].

It was difficult to validate the perceptions of the fishers on certain aspects of climate. However, the changes in rainfall pattern could be attributed to a shift in the prevailing rainfall and circulation regime for Malawi, resulting in reduced rainfall in mid-February [110], which is the main agricultural season. Our findings on the interseasonal and interannual rainfall variations are similar to those reported by Ngongondo et al. [111] for the Malawi's entire rainfall pattern. The observed climate variations in this study could be a true reflection of the entire Southern Africa region. The weather pattern in this region is affected by the influx of the Southwestern Indian Ocean during spring, and the shift of the tropical temperate cloud band sea surface temperature (SST) from the central south Atlantic and off the coast of Southwest Africa [112–114].

Our findings further corroborate other studies in Malawi [109,115] that also reported conflicting messages between the perceptions of farmers and the time series climate data, and attributed these differences to the ease of remembering the occurrence of extreme climate events. However, contrary to our findings, Kalanda-Johua et al. [58] reported that the perceptions of farmers in the Mulanje district of Malawi were similar to the meteorological data, but these perceptions reflected climate variability just like in our study. The failure to ascertain the fishers' perceptions as significant climatic changes could mean that the climate was variable [116].

6.2. Perceived Impact of Climate Change on Fish Catches

Our findings demonstrated the awareness of fishers' knowledge on the causes of poor fish catches over time. One of the factors raised by the fishers was changes in climate (low precipitation, droughts and high temperatures). Despite the insignificant trends in our meteorological data, the perceived changes directly affect fish production [117–122]. For instance, high rainfall brings nutrient fluxes to the lake through rivers and boosts fish production [123]. High temperature and strong winds also facilitate primary production which makes food available for fish through water mixing [124]. Despite high temperatures being good for primary production, Lake Malawi has a complex circulation pattern in its surface temperature meaning that there is no well-defined temperature distribution pattern [125]. Furthermore, the respondents during the focus group discussions cited low lake levels as being another cause of low fish catches. However, in Lake Malawi, low lake levels increase the speciation process which increases fish abundance [126]. In general, these perceived changes have the capacity to increase fish catches and distribution, unlike in agriculture. Therefore, the fishers might have constructed their perceptions based on agricultural failures, because even though these respondents all own fishing gear, their main occupation was shown to be significantly different from their income source. This might mean they are part-time fishers but are predominantly farmers. Thus, the problem of low fish catches cannot be entirely attributed to the perceived changes in climate. The study also recognizes that a clear

picture of the direct relationship between the perceived climate variables and fish catches can only be validated through modelling of the two, which was beyond the scope of this study.

Furthermore, the study also failed to attribute low fish catches to fishing location, because many fishers (76%) were operating in the deep offshore waters known to have a huge unexploited fish biomass [127], but they still experienced low fish catches. Therefore, the problem of low fish abundance could be distributed throughout the entire lake.

This study also noted an increase in unsustainable fishing gears, which includes small mesh sized nets without size selectivity for catching fish [128]. The reduced mesh sizes and increased fishing time observed in this study could be a sign of an overfished resource, as a response to decline in the large fish sizes at the top of the food web [129]. These results corroborate with [12,13,130,131] who all reported that Malawi fisheries are overexploited. Even though the use of small mesh sized nets is illegal in Malawi fisheries [97], fishers are still using them. This could be attributed to weak enforcement of the laws and also to the need to survive. However, our results also corroborate with Ha and van Dijk [132], who found that the violation of fishing regulations by Vietnamese fishers had caused resource decline. However, these results provide a platform to explore other livelihood sources for the fishers to deter unsustainable fishery exploitation. The observed behaviour of the fishers occurred due to their vulnerability, causing them to adopt and develop strategies to cope with the situation.

6.3. Coping Strategies for Low Fish Catches and Their Determinant Factors

Apart from the observed unsustainable fishing methods, the study also revealed that a proportion of the fishers (25%) had not changed their fishing behaviour. Failure to adjust to low fish catches despite having access to weather information, could be interpreted as the fisheries still being a major livelihood source. This corroborates with Bryan et al. [133] who found that not all farmers who had perceived climatic changes had adjusted their behaviour. Additionally [134] found that an increase in fishing dependency could be a sign of decreasing viability of agricultural livelihood opportunities, as small-scale fishers are opportunists, driven by fluctuating fish catches.

On the other hand, others (75%) expanded agricultural land, ventured into small businesses, and provided casual labour services to agriculture and fishing. The presence of many coping strategies and the ability to widen alternative strategies has been found to characterize fishers subjected to the effects of climate change [135]. However, small-scale fishers in Malawi are also known to have several coping strategies for low fish catches, which include farming and migrating to other fishing grounds [7,134,136,137]. The adjustment of livelihood sources in this study may be not permanent but rather, a diversification strategy as a response to low fish catches [7,138]. These strategies are meant to spread out efforts between the most profitable activities [137], which includes agriculture, a sector that is a basic source of income for over 80% of Malawians [139].

However, the decision to adjust behaviour due to low fish catches was influenced by the household head's age, marital status, education level, annual income and membership to the fish conservation committee. All the coping strategies are labour-intensive and require physical strength, which older fishers are more likely to lack [140]. This study found that age increases the probability of adjusting. This could be the case because an increase in age is associated with having experience with practical solutions related to dealing with exposure to extreme weather events. These results corroborate with Bryan et al. [133], Pangapanga et al. [3] and Maddison [102], who conducted studies in Ethiopia, Malawi and several African countries, respectively, and also found that age significantly increases the propensity to adjust to the effects of climate change.

The study also observed that the magnitude of a fisher's annual income increased the likelihood of adjusting. High income levels build adaptive capacity [141] that could enable fishers to diversify into other initiatives. Families with high income levels are responsive to climate change [142]. High income from fishing promotes the willingness to invest into other initiatives that provide a cushion against household emergencies caused by future low fish catches [143].

We also found out that education increases the probability of adjusting because education is normally positively correlated to access to climate information [102,133,142]. The more educated the fishers are, the more climate information they have; this is important in helping them to be forward-looking in their plans, compared to being reactional.

Furthermore, the reason why marital status was a significant factor could be the fact that the study area is predominant matrilineal [144]. In their study, Nagoli and Chiwona-Karltun [33] revealed that matrilineal systems affect coping strategies, as in most cases, men have to leave their households in search of green pastures. This practice improves the financial status of the family, as it supplements fishing incomes with remittances.

The study revealed that being a member of the fish conservation club reduced the probability of adjusting. This might be contrary to good steward practice in sustainable fisheries management where members of such clubs should be the ones spearheading conservation initiatives [145]. However, in this study, only 35% of those who adjusted were members of such clubs. Their persistence in fishing could be attributed to knowledge of the fishing locations where good stocks of fish can be exploited, as most of them stated that they fish in the offshore areas.

Despite the logistic regression model being correctly specified, some obvious variables (e.g., household size, household head sex) which are known to affect coping behaviour were not statistically significant ($p > 0.05$) [100,140,146]. For example, gender influences coping behaviour due to the different roles that men and women have to do, as determined by sociocultural constructs [147], like ownership of fishing gears and participation in other fishery-related activities [148]. Furthermore, this might explain why our sample size was biased towards men as the act of catching fish is male-dominated [149].

7. Conclusions

Fishers of Nkhotakota perceive that the climate has changed and in this study, they explained how this has affected their fishing behaviour. They perceive that they have experienced increased incidences of droughts, erratic rainfall, extremely hot temperatures, Mwera winds and flooding. However, these perceptions did not corroborate with time series meteorological data for the area, which reveals a variable climate and non-significant changes. Despite these perceived changes and low fish catches, fishing is still the main livelihood source. The study further failed to fully ascertain whether low fish catches are due to climate change, even though climate plays a major role in fish distribution. There is a need to model climate trends and fish catches to ascertain such a relationship. However, low fish catches could be influenced by the long-term use of destructive and unselective fishing gears, leading to overfishing. The results indicate the need to be cautious of how extreme weather events are defined and framed. This has implications for the development of local sustainable adaptation strategies, which rely on the use of perceptions.

This study has also shown that fishers have multiple livelihood strategies to cope with the experienced changes and this enhances their adaptive capacity. Fishers adjusted to low fish catches by expanding their agricultural farming land, running small businesses and providing casual labour services to farming and fishing. The ability to cope with such changes was strongly influenced by different socioeconomic factors. Despite the need for the fishers to adapt to the climate-related changes, the identified coping strategies might have negative long-term impacts on the availability of fish, which is still a cheap protein source in Malawi. Some of these choices for adjusting are not permanent and might not give the fishery room to return to its normal state. Therefore, either the fishers should be regulated through closed seasons or encouraged to use sustainable fishing methods, but this requires the Malawi Government to institute strong policies to control input targets for fisheries. A study of this nature could also be used to inform the management of other natural resource-based livelihoods when claims related to climate change are perceived to affect livelihoods.

Supplementary Materials: The following are available online at http://www.mdpi.com/2225-1154/6/2/34/s1, File S1: Household survey questionnaire, File S2: Correlation results for factors affecting adaptation to low fish catches.

Author Contributions: Moses Majid Limuwa was involved in designing the research, data collection and data analysis, and developing the manuscript. Bishal Kumar Sitaula and Trond Storebakken were involved significantly at each stage of the manuscript's writing as well as in designing the study, field scoping, and in the review of the study tools. Friday Njaya reviewed the study tools and framing of the context in which the study was conducted and was also involved in reviewing of the manuscript.

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Paper II

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A GENDERED PERSPECTIVE ON THE FISH VALUE CHAIN, LIVELIHOOD PATTERNS AND COPING STRATEGIES UNDER CLIMATE CHANGE - INSIGHTS FROM MALAWI'S SMALL-SCALE FISHERIES

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ABSTRACT

In Malawi, fish is a form of livelihood to many poor people, despite fluctuations in catches. Female participation in natural resource activities, including fisheries improve livelihoods. However, female participation in Malawi fisheries has historically been low compared to their role in agriculture. In this article, gender roles in the fish value chain, livelihood patterns and gendered coping strategies in Malawi's small-scale fisheries under the effects of climate change were analysed. The analysis is based on interviews conducted on the western shores of Lake Malawi in two phases between January 2016 to June 2016 and June 2017 to July 2017. Qualitative and quantitative research methods were used to collect and analyse data from randomly sampled male and female household heads who own fishing gears and vessels. The study showed no significant differences between men and women in their perceptions of climate change in the last 30 years. The respondents' perceptions on ecosystem changes were significantly different for a number of trees and vegetation cover. However, there are significant differences on how male and female respondents perceived changes in fish catches and species composition. The statistically significant results showing differences between fish value chain activities and gender are attributed to the well-defined division of roles and responsibilities within Malawi fisheries. Respondents acknowledged the increased participation of women in grading, processing and selling fish in urban markets compared to the past. However, increased participation of women in fisheries was not due to perceived changes in climate but due to ownership of fishing gear and economic empowerment through development projects. Furthermore, this participation did not result in women having power to control or decide how to use fisheries related income. The study also shows women have a higher proportion of fisheries related monthly income than men. The main income sources are gendered and have changed in the last twenty years from heavily relying on agriculture to fisheries related sources. These changes could be attributed to climate related changes among other drivers. The study further observed significant differences in coping strategies between men and women attributed to households' social construction. Men ventured into fisheries and agriculture related initiatives while women were more into business initiatives. The findings suggest gender considerations regarding access to natural resources have implications on sustainable livelihoods. It is suggested that changes that transform gender relations should be put in place to improve women's ability to bargain.

Key words: Climate change, coping, fisheries, gender, livelihoods, Malawi, perceptions, value chain

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INTRODUCTION

Failure to consider gender in rural livelihoods increases vulnerability to climate-induced effects [1]. This vulnerability is socially produced and influenced by many factors including poverty, culture, political processes, place and time [2]. Exposure and sensitivity to such effects vary between men and women [3], and rural women suffer most because their livelihoods depend directly on ecosystems services [4]. One such ecosystem service is Malawi fisheries, where little is known about how men and women are affected by climate-induced vulnerabilities.

Malawi fisheries are a source of animal protein, especially for the majority of inhabitants who live in rural areas. In addition, fisheries contribute about 4% of Malawi's annual Gross Domestic Product (GDP) [5]. However, Malawians' fish consumption decreased by 60% between the 1970s and 2015 due to low fish catches [5]. Low fish catches are attributed to overfishing caused by population increase [6] and climate related events [7], among other factors. Despite this effect on fishers' livelihoods, women's participation in natural resource activities improves household incomes and food security [8].

Women and men often interact with different parts of the fisheries' ecosystem [9]. Women take part in many fisheries related activities, but their contribution is often invisible because they consider the work as part of their traditional home duties [10]. This results in gender-biased perceptions that reinforce the male-dominant vision of fisheries [11]. Therefore, without a complete understanding of the complexity of gender roles, sustainable livelihoods cannot be achieved. For example, the lack of documentation of women's roles in fisheries leads to policies biased towards solving male-oriented overfishing problems at the expense of policies that create sustainable livelihoods at the community level [12].

The role of women in Malawian fisheries is not as properly documented as their roles in agriculture [13]. Within the fish value chain in Malawi, women dominate low value (sun-dried) fish products for smaller species, while men dominate high value products like smoked large fish species [14]. Smoking adds more value to fish products compared to sun dried [ibid]. Furthermore, gender relations and fish catch fluctuations have received little attention in areas where climate related impacts are recurrent [15].

Fluctuating fish catches affect livelihoods for women and men [3]. Therefore, if sustainable resource management and community well-being are to be maintained, men and women must be mobilized together. Women have unique knowledge and skills, which add value in responding to effects of climate change more effectively and sustainably [16]. This article seeks to analyse gender roles in the fish value chain, livelihoods patterns and coping strategies in Malawi's small-scale fisheries under the effects of climate change. The study aims to provide knowledge to inform policies and interventions that can improve sustainable livelihoods of Malawi fishers. The research explored the following questions: i). do women and men in fishing communities perceive changes in weather trends and the ecosystem differently?, ii). do women and men perceive changes in fish catches and species composition differently?, iii). to what extent can changing gender roles in the fish value chain be attributed to climate change?, iv).

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has a shift in household livelihoods been observed over the past 20 years?, and v). do women and men in fishing communities employ different strategies to cope with climate change?

MATERIALS AND METHODS

Study area and data collection

This study was conducted in the Nkhotakota district on the western shores of Lake Malawi between Global Positioning System (GPS) Coordinates: 12°37'40.5"S 34°10'32.2''E and 12°37'40.5''S 34°10'32.2''E (Figure 1), from January 2016 to June 2016 and from June 2017 to July 2017. The study site was chosen because it is exposed to environment-induced effects and is also a priority area for the implementation of the National Adaptation Plan of Action (NAPA) on climate change [17]. Nkhotakota's fishers make up 14% of the total small-scale fishers of Malawi with women owning 2% of the total fishing gear [18].

In order to explore the research questions, we combined qualitative and quantitative research approaches. Prior to detailed household surveys; exploratory surveys, participatory and field observations were conducted to contextualize the study. Through these processes, research tools (household survey questionnaire, checklists for focus group discussions and key informant interviews) were developed and pre-tested for consistency. Furthermore, consent to conduct the study was granted by both village chiefs and respondents. The study randomly sampled household heads from families who owned either a fishing gear or a vessel. The lists on which random sampling was based were retrieved from local fisheries management committees. Validity and reliability of the household surveys were also strengthened by conducting five (5) sets of focus group discussions (FGDs) and key informant interviews (KIIs) as a follow- up to the key outcomes from the household survey. Each FGD was comprised of a group of 10 women and men of mixed ages who were interviewed separately and later combined to ensure unbiased responses. The KIIs included fishers (gear owners and crew members), sellers, District Assembly officials, chiefs and local fisheries management committee members.

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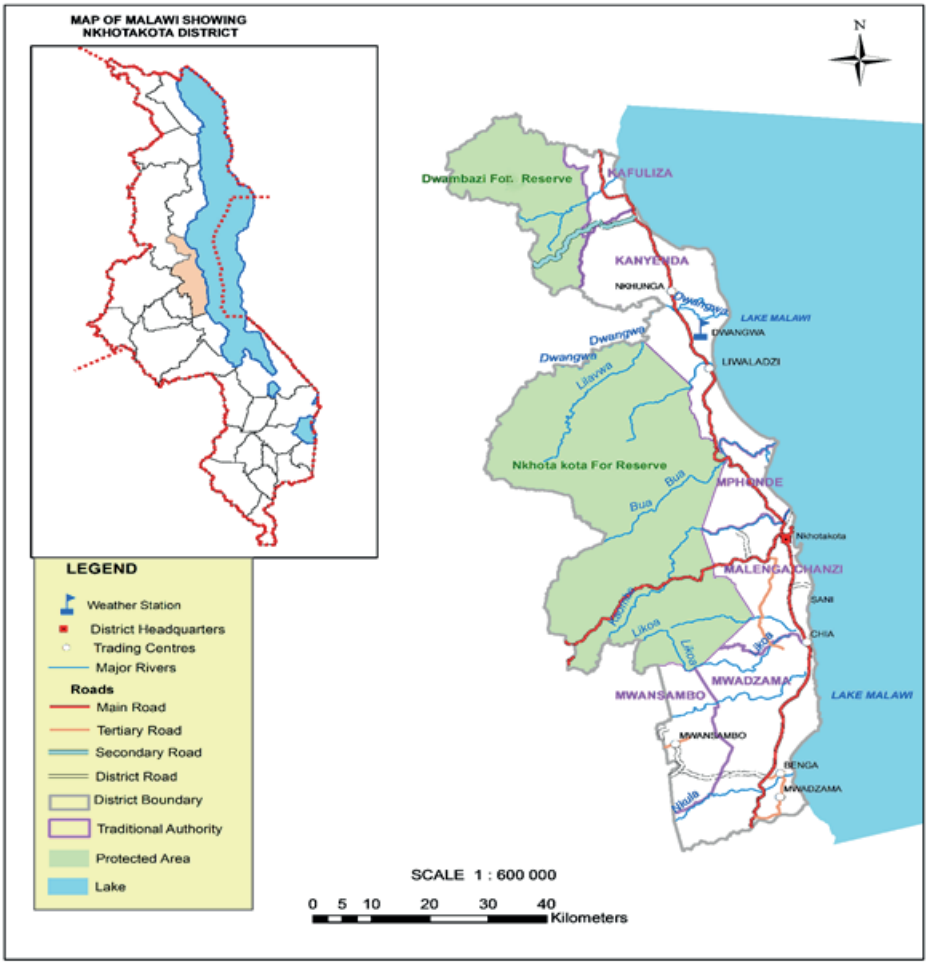

Figure 1: Map of Malawi showing Nkhotakota district and the study area

Data analysis

The household concept, despite its weakness in not accounting for intra-household differences in gender studies, was used as a unit of analysis because fishing gears were mostly owned by household heads. This concept guided analysis of responses from the research questions. Furthermore, it strengthened the application of the Harvard Analytical Framework (HAF) in determining gender roles. The HAF is part of a broader framework of Gender and Development (GAD) [19]. This study concentrated on gender roles which included: who does what, who does it most, who is most experienced in that activity and who has access to and control of the benefits from fishing related activities. The framework further provided a platform to analyze power relations between women and men on different fish value chain activities.

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Qualitative data was analysed using content analysis for related themes. Direct quotations were used to explain, support and clarify important issues observed by the respondents. Descriptive statistics (means, ranges, frequencies and proportions) were analysed using IBM SPSS Statistics 24 and Stata version 14.2. Cross tabulations were used to determine statistical relationships of several household characteristics (marital status, kinship, religion, tribal affiliation, perceptions on climate change and fish catches, gender roles, income sources and coping strategies) between men and women respondents. The study also used an independent sample t-test to compare experience associated with fishing related activities, total fisheries incomes and the proportion (%) of fisheries-related total monthly income between men and women respondents.

RESULTS AND DISCUSSION

Characteristics of study respondents

The study randomly sampled 113 households with a respective 65% and 35% of male and female respondents. A full description of the respondents' characteristics is shown in Table 1. The mean ages for men and women were 39.8 and 39.4 years old, respectively. The respondents' age ranged as from 20 to 64 years for men and from 21 to 94 years for women. The statistically significant ($t\ (12.76) = 4.6,\ p = 0.00$) average time in years the households had been involved in fishing-related activities for men and women respondents were 16.4 and 7.4 years, respectively. Although these results suggest men have been involved in fishing related activities for a longer time than women, the higher age range for women suggests no age restrictions in conducting fisheries-related activities.

The study revealed the majority of respondents (men and women) had formal education and were married. There were significant differences ($\chi^2 = 19.59,\ df = 4,\ p = 0.001$) between the marital status of men and women. The higher proportion of married men (89%) compared to women (60%) could be caused by a higher level of divorce for women (18%) than men (0%). Furthermore, single or divorced women are also more likely to go into occupations not traditional for women, than married women.

The results also showed significant differences ($\chi^2 = 9.67,\ df = 1,\ p<0.05$) between kinship (patrilineal and matrilineal) of men and women respondents. Table 1 shows the majority of women (74%) were from matrilineal kinship compared to 58% of men. These results confirm the standard norm in the study area, which is that Chewa is dominated by and follows matrilineal settings. The Chewa tribe domination (69%) was confirmed from sampled households, while other tribes (Tumbuka, Tonga, Yao, Lhomwe and Ngoni) were a small proportion. These findings could also reflect possibilities of intermarriages with patrilineal tribes like the Tonga and Tumbuka who migrated to the study area [20]. Furthermore, there was a significant difference between tribal affiliation and religion ($\chi^2 = 34.12,\ df = 6,\ p<0.001$). These findings suggest that religious affiliation influences tribal tenets [21], which result in socially-constructed roles, and has major implications on power relations within households.

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Table 2 summarizes ownership of major capital assets for respondents. Even though it was easy to access land in the study area [22], the study showed that half of the respondents (51%) did not own a house or land but rented a house and agricultural land. This could indicate temporary residence as some respondents (53%) had migrated to the area.

The households also owned other assets like bicycles (62%) and an ox cart (1%). The bicycle mode of transport in the study area eases mobility challenges that are known to affect livelihoods of women and girls [23]. The majority (95%) of respondents had no electricity. Regardless, some (19%) respondents owned assets like television sets, which require electricity for operation. Ownership of television sets could be attributed to the increase in solar energy use.

Do women and men perceive changes in the weather trends and the ecosystem differently?

The majority (>90%) of respondents reported experiencing significant changes in temperature and rainfall (Figure 2). These changes include increased incidences of extreme hot temperatures, late onset of and erratic rainfall, floods and droughts. However, there were no statistical significance differences ($\chi^2 = 453$, $df = 1$, $p > 0.05$), between men and women's perceptions of these changes in the last 30 years.

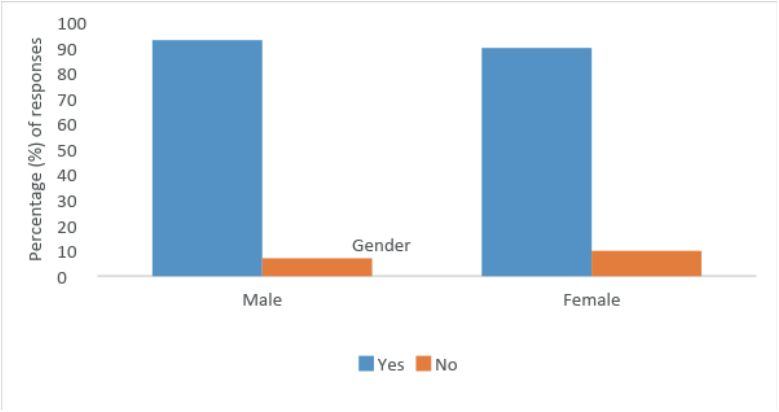

Figure 2: Respondents' perceived changes in weather patterns by sex over the last 30 years

The perceptions of respondents were based on their experiences of long-term weather exposure in the last 30 years [24]. The high average age of respondents (39 years) provided a good platform to support having experienced such changes by reducing challenges, which arise when people interpret trends from a few recent events [25]. Even though age is a good indicator for experiencing exposure to the changes, perceptions are furthermore influenced by the ability to recall and define these incidences using lived experiences as a baseline for comparison [26].

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Table 3 shows frequency of droughts and floods in the study area over the last 30 years. The majority of respondents (>90%) acknowledged that the rainfall pattern had been erratic resulting in extreme high temperatures. This could be as a result of Malawi's monthly precipitation pattern, which has been unstable with increased frequencies of inter-annual variabilities [27]. About half of the respondents had witnessed less than three (3) drought incidents attributed to low precipitation, whereas the other half had not witnessed any flooding event. There were no statistically significant differences between respondents' sex and the perceived number of droughts and floods.

The perceived ecosystem changes in the study area are broadly summarized in Table 4. The majority of respondents (men and women) acknowledged significant ecosystem changes in beach size, number of trees, number of reeds, wetland size, river flow, river size and vegetation cover. Furthermore, men and women respondents perceived vegetation cover changes ($\chi^2 = 3.2, df = 1, p<0.01$) and the extent to which the number of trees had changed ($\chi^2 = 11.07, df = 2, p<0.001$) differently. The women's perceptions could be a reflection of knowledge gained by travelling long distances to collect firewood for cooking. Beach size increase suggested low water levels in Lake Malawi. The number of trees, vegetation, reeds, wetlands size, river flow and size had also decreased. However, low precipitation and extreme hot temperatures were perceived by the households to be the main driver of such changes. Additionally, these changes have implications on the livelihoods of fishers [4].

These results also reflect some responses regarding ecosystem changes given during a focus group discussion of men and women: *"Where we are sitting right now and where we built our houses used to be part of Lake Malawi but now it is all dry."* (Group discussion with author, Site #1, 2017).

Do women and men perceive changes in fish catches and species composition differently?

The study showed that the majority (99%) of respondents reported poor fish catches in the last 16 years. Some male respondents (63%) reported decreased probability of catching some fish species compared to 84% of the female respondents. There are statistically significant differences ($\chi^2 = 4.631, df = 1, p<0.05$) between men and women's perceptions with regard to poor fish catches in the study area. These differences could be attributed to different species preferences because catching fish is mostly a male job, while women commonly sell or consume and might not know as much about fish species [12].

The most common fish species in the area used to be *Copadichromis virginalis*, *Engraulicypris sardella and Oreochromis.* Among these three fish species, respondents ranked *Engraulicypris sardella* and *Copadichromis virginalis* as the most important fish species of today for food and income, whereas *Oreochromis species* were rarely caught. Furthermore, respondents cited an increase in illegal fishing gears, migration of fish to offshore areas, and drought incidents as some reasons for low fish catches. Climate-related factors like rainfall affect fish catches because turbid waters from rainfall provide food to fish and also hinder fish's visibility from any possible fishing traps and nets [28].

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The responses of men and women from another focus group discussion on effects of extreme weather events on fish availability highlighted how low catches could be attributed to climate related factors: "*We are challenged by droughts, up to the extent of skipping meals some days. We have the lake nearby but even to catch the fish is not easy because catching more fish is a factor of getting a lot of rain."* (Group discussion to author, Site #2, 2016).

To what extent can changing gender roles in fisheries be attributed to climate change?

Results from the study show the three important fish species in the study area have a similar value chain. This supports previous results [14] and could be attributed to the number of times these activities are done. Fish value chain activities like identification of fishing grounds, buying nets, boats and fuel, identification of fishing crew and catching fish were male dominated, while women dominated fish post-harvest activities (Table 5). There were statistically significant differences ($\chi 2 = 38.87$, $df = 4$, $p<0.0001$) between fish value chain activities and respondents' sex. This may suggest well-defined division of gender roles in fisheries [29], which are guided by social-cultural institutions [11, 12].

In general, respondents acknowledged increased participation of women in fish grading (33%), selling (48%), processing (50%) and selling in urban markets (33%) compared to the past. The study further provides evidence that transformation of gender roles in the fish value chain were not due to perceived changes in climate ($p>0.05$). Instead, the general participation of women in fisheries could be attributed to ownership of fishing equipment [30] and empowerment activities by many projects promoting women's leadership roles in economic activities [31]. Even though female participation increased overall, their participation in giving advice to their employed fishing crew on potential fishing grounds (2%), buying fuel for fishing boats (1%) and recruiting fishing crew (0%) remained low.

Here is a response on participation of women in fisheries given during a key informant interview by a female fish trader: *"Now things have changed, I thought I was helping my husband to supplement money for our better lives. Now his money is for his own things and mine is for supporting the family. Our involvement in fisheries is due to economic empowerment in order to support our households and has nothing to do with climate change."* (Interview with a female fish trader to author, Site # 3, 2017).

Table 6 shows the implications of women's participation in fisheries. These include improved socio-economic status of their households and more women were now part of the local fisheries management committees. The participation also increased transactional sex for the women as cited by 10% of the men. Another implication was failure of women to control and decide how to use income from fisheries-related activities. The lack of power could be a result of intermarriages between migrants of patriarchal origin to matrilineal locals [20]. Gender power relations in most traditional African societies have patriarchal underpinnings [32].

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Has a shift in household livelihoods been observed in the last 20 years?
Table 7 summarizes the mean monthly fisheries income and its proportion to total household income. Income differences were statistically significant ($t\ (20) = 2.5,\ p<0.05$) between men and women. A higher proportion of income came from fisheries-related activities for women (76-91%) than men (63-69%). Income from selling of fish is important throughout the year, particularly for women.

Results indicate differences in fish selling locations. Most male respondents (78%) sold their fresh fish at landing sites to processors and traders. These results suggest men were eager to reduce waiting time of selling fish before returning to the water for another fishing round. Women sold their fish within village markets (27%), district markets (30%) and urban markets (30%) as dried (60%), smoked (16%) and fried (12%) goods. Women preferred to sell their fish in urban markets due to low prices in the village and district markets. This is similar for women in agriculture who have responded to low selling prices of their farm produce by selling at distant urban markets [32].

Table 8 shows that main income sources had changed in the last twenty years. There are statistically significant differences $(\chi 2= 7.9,\ df = 4,\ p<0.1)$ between perceived changes in climate and household income sources for the last 20 years. Respondents no longer rely as heavily on agriculture-based incomes as they did twenty years ago. These changes could be attributed to low agricultural productivity. Fisheries offered an easy alternative because of proximity to the open access lake [33]. These results might suggest climate as a main driver for changes in income source.

There were also statistically significant differences between income sources (current or 20 years ago) and respondents' sex, suggesting income sources to be gendered. For example, between 1996 and 2016, more women were selling food crops compared to selling fish. Whereas the majority of men used to be casual employees in fisheries in the past but now, they were owners of fishing gears and vessels.

Do women and men employ different strategies to cope with climate change?
Table 9 shows how the majority of respondents diversify livelihoods due to low fish catches. Even though households indicated a shift from agriculture to fisheries as the income source, more men than women are involved in agriculture as a livelihood diversification measure. These shifts by respondents suggest circular patterns [34] as livelihoods seem to revolve around fisheries, agriculture and businesses (Table 8). Half of the women (50%) and 20% of the men were migrating to other fishing areas. Surprisingly, women who do not have power and control over household income are allowed by their husbands to migrate between fishing sites to buy fish for resale. This behaviour could be driven by dominant control of men over women's earnings [35]. However, 20% of men who did not migrate to other fishing sites coped by intensifying offshore fishing. Migrating to other fishing areas is a good coping strategy [36], which also provides time for fish stocks to rejuvenate [37]. However, migration increases competition between fishers and this affects sustainability of the fishery [38]. Women also used group coping strategies like Village Saving Loans (VSLs). Coping with changes as a group is common for women [29] since it improves their bargaining power [3]. Having many coping strategies and flexibility between which to switch suggest opportunistic behaviour, which could lead to unsustainable natural resources use [39].

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The difference in coping strategies between men and women was statistically significant *($\chi 2$, $p<0.001$),* suggesting coping strategies are gendered. This could be attributed to the adaptive nature of men and women, which is associated with cultural norms [40].

During a men's focus group discussions on their coping strategies, the following was stated to support the results from the household survey: "*We have improved our coping to the changes by using illegal fishing gears and providing labour to upland farms and while at the same time increasing the price of the fish."* (Group discussion to author, Site # 4, 2016).

CONCLUSION

Gender consideration is an important social aspect to achieving sustainable livelihoods. Thus, a study to analyse gender roles in fish value chain, livelihoods patterns and coping strategies under climate change in small-scale fisheries of Malawi was conducted.

The study has revealed that men and women had similar perceptions to common extreme weather events in the study area. The extreme weather events were hot temperatures, late onset and erratic precipitation, floods and droughts. Yet men and women's perceptions on ecosystem changes like the number of trees and vegetation cover differed.

The impacts of the perceived extreme weather events between men and women included decreased fish catches. The changes in climate, however, did not influence the increase of women's participation in fish grading, processing and selling fish in urban markets. The women's participation was attributed to increased investment in fisheries related activities. The participation of women in fisheries related activities did not result in them having power to control assets and benefits from fisheries. Their participation, however, resulted into improved household welfare concerning food and income security. Due to the participation of women in fisheries related activities, more women were also incorporated in the local fisheries governing structures than in the past.

The study further noted a shift in livelihood patterns during the last 20 years from agricultural to fisheries and the shift was significantly different between men and women. In the last 20 years, that is between 1996 and 2016 more women were selling food crops compared to fisheries related activities. During the same period, men who used to do agricultural related activities and working in fisheries as casual laborers, were now doing less agricultural related activities compared to fishing. These changes might be a reflection of how agricultural productivity was affected by changes related to climate.

Despite such shifts in livelihoods, men and women also coped with the low fish catches differently. Women's strategies were more business oriented than men who were oriented towards agriculture and fisheries. Additionally, coping also created a platform for equated division of labour within households, especially when women travel to other fish landing sites and markets far away from their homesteads.

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The findings are important in implementing gender inclusive policies related to livelihood improvement and coping with fluctuating natural resources. This study provides an overview on how livelihood coping strategies can be mainstreamed in policies without losing focus of the different roles men and women play. Furthermore, these policies can be strengthened by validating local perceptions on climate change and fish catches with conventional scientific knowledge.

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Table 1: Household characteristics of the respondents (N=113)

Characteristic		Male %	Female %
Marital Status	Married	89	60.0
	Single	5.5	5.0
	Widowed	4.1	15.0
	Co-habiting	1.4	2.5
	Divorced	0	17.5
Education level	No formal	12.3	22.5
	Primary	56.2	62.5
	Secondary	31.5	15.0
Main income source	Agriculture	5.4	2.5
	Fishing	90.4	87.5
	Business	2.7	10.0
Kinship	Patrilineal	58.0	25.7
	Matrilineal	42.0	74.3
Religion	Muslim	50.7	55.0
	Christian	47.9	45.0

Table 2: Major capital assets for the households (N=113)

Characteristic		**Frequency**	**Percent (%)**
House ownership	Yes	55	49
	No	58	51
Type of house	Brick grass thatched	53	47
	Brick iron thatched	43	38
	Mud grass thatched	15	13
Ox cart	Yes	1	1
	No	112	99
Bicycle ownership	Yes	70	62
	None	43	38
Cellphone ownership	Yes	83	73
	None	30	27
Television ownership	Yes	21	19
	None	92	81
Access to electricity	Yes	6	5
	None	107	95
Solar panel ownership	Yes	16	14
	None	89	79

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Table 3: Perceived proportion (%) for frequency of floods and droughts incidences observed in the last 30 years by the respondents (N=113)

	Droughts		Floods	
Frequency	**Male**	**Female**	**Male**	**Female**
< 3 times	54.4	55.3	46.6	50
4 – 6 times	14.7	5.3	10.3	7.1
> 6 times	13.2	26.3	8.6	0
never witnessed	17.6	13.2	34.5	42.9

Table 4: Proportions (%) of perceived ecosystem changes in the last 30 years by the respondents in Nkhotakota (N=113)

Changes	**Degree of change**		
	Increased	Decreased	Same
Beach size	64.3	24.1	11.6
Number of tress	16.1	77.7	6.3
Reeds	12.6	78.4	8.1
Wetland size	13.9	72.2	13.9
River flow	7.3	79.1	13.6
River size	4.5	84.5	10.9
Vegetation	2.7	86.6	10.7
Fish kills	1.0	86.7	13.3

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Table 5: Nkhotakota fish value chain, roles, access and control of resource for men and women on *Copadichromis virginalis*, *Engraulicypris sadella and Oreochromis spp.* fish species (N=113)

Gender role	Who does it most?			Most knowledgeable in the activity			Changes to who was doing it in the past.		Frequency of activity
Fish value chain activity	Male (%)	Female (%)	Male & Female (%)	Male (%)	Female (%)	Male & Female (%)	Yes (%)	No (%)	
Identification of fishing grounds	98	2	0	100	0	0	0	100	Everyday
Buying of fishing nets	99	1	0	100	0	0	10	90	When worn out
Buying of fishing vessels	97	1	2	99	0	1	9	91	When worn out
Buying of fuel for fishing vessels	98	1	1	97	0	3	4	96	Everyday
Identification of fishing crew	99	0	1	99	0	1	0	100	Everyday
Catching of fish	99	0	1	99	0	1	0	100	Everyday
Grading of fish	59	20	21	65	14	21	33	67	Everyday
Selling of fish	35	42	23	36	34	30	48	52	Everyday
Processing of fish	20	54	26	21	48	31	50	50	Everyday
Selling fish to urban markets	30	45	25	24	41	35	33	67	Everyday
Who has the right to use the catch?	72	14	14	78	8	14	8	92	Everyday
Who controls the money from fish sales?	85	9	6	83	10	7	5	95	Everyday
Who decides how much to use?	80	15	5	82	12	6	6	94	Everyday

Table 6: Proportions (%) of perceptions on implications of women's participation in fisheries by the respondents

Implications of women participation in fisheries	Male	Female	Total
Increase in sexual behaviour	6	0	6
Increased joint control of resources	4	0	4
Increased demand for fish than in the past	4	0	4
Improved social economic status	13	12	26
More women in fisheries management	19	12	31
More women in fish processing and selling	7	2	9
Increased control of resources by women	7	3	10
Increase in destabilization of families	1	0	1
No control of resources	3	6	9
Total (%)	**65**	**35**	**100**

Note: N=113. Cross tabulations: $\chi^2 = 18.88$, $df = 8$, $p = 0.016$

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Table 7: Nkhotakota female and male monthly fisheries income (US$) and its proportions (%) from the total household income for the period June 2015 to April 2016 (N=113)

	Female		Male	
Month	Mean Fisheries Income (US$)	Proportion of total Income from fish (%)	Mean Fisheries Income (US$)	Proportion of total Income from fish (%)
June	53.7	90.00	115.8	65.44
July	44.0	91.15	73.2	68.64
August	86.5	89.00	80.2	68.78
September	66.3	87.67	72.3	68.15
October	70.1	86.75	80.3	68.38
November	63.8	82.07	83.0	66.29
December	85.1	76.13	84.3	68.62
January	61.2	86.25	68.9	65.47
February	54.5	83.85	65.8	64.03
March	37.3	77.00	60.8	62.90
April	46.2	86.50	65.0	63.23

Exchange rate: 1US$ = MK 733 as at March 2017

Table 8: Comparison of income sources in 2016 (current) and 20 years ago by men and women (N=113)

Income source	Current (2016)		20 years ago	
	Male (%)	Female (%)	Male (%)	Female (%)
Sale of fish	70	75.0	17.8	12.5
casual employment in fisheries	4	0	32.9	0
Sale of food crops	15	7.5	11.0	42.5
Sale of cash crops	3	7.5	0	5.0
Sale of livestock	0	2.5	0	0
Sale of livestock products	0	2.5	0	0
Business	3	3	0	0
Casual employment in farming activities	5	2	2.7	0
Under aged respondents who were under 20 years ago	-	-	35.6	40.0
Total (%)	**100**	**100.0**	**100.0**	**100.0**

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Table 9: Female and male respondents coping strategies to low fish catches (N=113)

Coping strategy	Female (%)	Male (%)
Selling fish to upland markets	2.0	14.0
Village Saving Loans (VSL)	10.0	-
Agriculture	5.0	14.0
Casual labour	8.0	11.0
Petty businesses	18.0	4.0
Did not adapt	6.2	5.0
Circular migration to other fishing areas	50.0	20.0
Food rationing	1.0	-
Offshore fishing	-	20.0

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Paper III

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Article

Is Fish Farming an Illusion for Lake Malawi Riparian Communities under Environmental Changes?

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Abstract: Global environmental changes have negatively affected many food systems while the demand for food has continued to rise. An urgent need exists to identify other sustainable means of producing food. This is a case in Malawi, where capture fisheries and agriculture are not supplying sufficient food. Fish farming food systems by communities who rely on inland fisheries have not been evaluated. Therefore, a study was conducted in two phases: January 2016 to May 2016 and in July 2017 to evaluate if fish farming could sustainably support livelihoods of Lake Malawi riparian communities. We used mixed methods to collect and analyze data. The data collection methods included explorative surveys, household survey interviews, focus group discussion and key informant interviews. Qualitative data was analyzed using content analysis for themes. This identified themes that were quantitatively analyzed using descriptive and inferential statistics. We observed that fish farming was dominated by men and also not the main occupation for the respondents despite owning fishponds. The respondents have water and land, which are prerequisite for any farming. The study also observed fish farming production challenges related to quality fingerlings, formulated diets, and extension services. Cases of food insecurity amongst the respondents were also prevalent due to lack of food to cover the entire year. Weak synergies existed between fish farming and agriculture restricting bio-resource flow and water usage between these two food systems, meaning the outcomes of the food systems provide unsustainable diets. Furthermore, water availability, money spent on food, and cassava cropping increased fish farming participation. Whereas operating a bicycle taxi, casual labor, former fish farming, as well as application of agricultural wastes negatively affected fish farming. On the other hand, extreme weather events (increased incidences of droughts and floods) attributed to inter annual rainfall variation also negatively affected fish farming. The responses from Lake Malawi riparian communities indicate that they merely look upon fish farming as an alternative to capture fisheries than as an illusion. Nonetheless, the research provides a theoretical platform to explore the potential to develop sustainable fish farming food system adapted to such changes. Therefore, we have brought new evidence that progress of fish farming in Malawi is being made, but there is a long way to go before it can be considered successful and sustainable.

Keywords: food system; sustainable diets; agriculture; global environmental changes; fish farming; fisheries; food security; Malawi

1. Introduction

Global environmental changes challenge achieving sustainable development goals. For instance, global environmental changes derail achieving global food security, which is an outcome for many food systems [1]. Continuous exposure to global environmental changes renders many households vulnerable and unable to attain sustained livelihoods. Therefore, in order to devise ways to enhance livelihoods, there is need to understand available food systems and their role in providing livelihoods.

One such food system, which is less understood, is Lake Malawi, a home of 500–1000 endemic fish species [2]. This lake is super rich as it has many fish species compared to other lakes in the world. The lake provides many ecosystem services to communities around it [3–5]. It is the small scale fishers who mostly do the fishing and the majority of them use traditional fishing methods [6]. The majority (90%) of annual fish catches in Malawi are mostly from these small scale fishers [5].

Despite such attributes of Lake Malawi in providing ecosystem services, edible fish catches have decreased in the last three decades resulting into reduced consumption from 14 kg per year in 1970s to 4 kg in 2005 [7]. This picture is also similar at a global level [8–10]. Such low fish supply calls into question whether Malawi's fish still provides a cheaper source of animal protein compared to other livestock groups [5]. From an economic point of view, as the fish supply decreases, the demand goes up and in doing so the prices go up too. The decrease of fish diversity results in some species rarely being caught [3] and many also being categorized in the IUCN Red List as threatened towards extinction [11]. Fish eating habits have also changed as species which used to be considered inferior, like the ornamental species, are now considered edible [12]. Furthermore, climate projections for Malawi show increased temperatures and low precipitation [13,14], even though there is lack of research on how Malawi fisheries are directly affected by extreme weather events, but we could as well say, fisheries might equally be affected. This is because climate directly affects fish production and distribution [15–17].

Low fish catches render the fisheries food system unable to provide sustainable diets because fish is an essential source of nutrients recognized in most national dietary guidelines [18–20]. Despite low fish catches, the communities around Lake Malawi continue to exploit the waters due to few options for pursuing other livelihood sources. The coping mechanisms which have been employed by the majority of the fishers are not sustainable and do not conform with the FAO code of conduct for responsible fisheries [21]. These include use of non-selective fishing gears [3] and cultivating closer to the buffer zones of rivers, causing siltation, which affects breeding grounds for many fish species [22,23]. This behavior leads to catching more fish beyond the maximum sustainable yields. Therefore, mitigating for such uncertainties is important as it builds resilience of the people who live around Lake Malawi [24].

Unsustainable fishing is attributed to population increase and movement of people from other food systems which are also under immense pressure [5,25]. Lake Malawi is an open resource where anyone can just walk in and start fishing. In addition, the regulations set by the government in collaboration with the local communities have failed to yield positive behavior changes, as people need to survive [26]. However, this has led local communities to suffer most because their livelihoods are centered around fish.

Therefore, this calls for a holistic assessment of other food systems that could be promoted to support the livelihoods of Lake Malawi fishers. This might ease the fishing pressure being exerted on the already overfished resource. Malawi fishers migrate between agriculture and fisheries as major livelihood sources [27]. Nevertheless, just like fisheries, the Malawi agricultural sector has also been experiencing continuous low crop yields [28,29]. Global environmental changes is among the factors impacting Malawi's agriculture because of over-dependence on rainfall, which is characterized by erratic, late onset, early cessation, and low intensity [30,31].

While other food systems have failed to enhance food security of the fishers, fish farming in Malawi improves resilience against food and income shocks when agriculture is impacted by extreme weather events. Furthermore, there has been a great deal of integration between agriculture and fish

farming, which benefits both food systems [32]. Since most fishers in Malawi possess agricultural land, fish farming could be a solution to enhance sustainable diets [3,25,27].

In Malawi, fish farming has been practiced for over 100 years [33], but its impact as a food system to people who fish in Lake Malawi as a source of livelihood is not known. Yet, globally, aquaculture is the fastest growing food producing sub-sector [34]. Indeed, the total global supply of fish from aquaculture is projected to increase from 154 million tons in 2011 to 186 million tons by 2030 [35]. However, for many countries, aquaculture development and its uptake has been stagnant despite its potential to reduce income- and food-vulnerabilities [36–39]. Adopting fish farming as an outright coping mechanism requires understanding its implications for riparian communities.

Information on suitability of fish farming for people who rely on inland capture fisheries is scant. Therefore, the goal of this study is to provide information to understand the status of fish farming with a specific focus on how it could work as a livelihood strategy for small-scale fishers. Specifically, the research has the following objectives: (a) to assess the socio-economic characteristics of the existing fish farmers; (b) to assess the status of fish farming food system; (c) to analyze the impact of extreme weather events on fish farming and; (d) to assess food systems outcomes.

2. Fish Farming in Malawi

In establishing the suitability of fish farming as a possible livelihood strategy for Lake Malawi fishers, there is a need to understand the context of fish farming. In Malawi, fish farming dates back to 1908 when brown and rainbow trout fish were reared for sport. However, small scale fish farming started around the 1950s in the northern region of Malawi as a response by the British Colonial Office to improve supply and nutrition in its colonies [33].

Ever since the introduction of fish farming in Malawi, the majority of fish farmers are still small scale whose fish are raised in earthen ponds utilizing natural productivity [6]. On the other hand, there is only one large scale aquaculture company in the southern part of Lake Malawi and it uses salmon cages to raise local species [40] cited in [6]. The common species cultured are *Oreochromis karongae*, *Oreochromis shiranus*, *Tilapia rendalli*, and *Clarius gariepinus* and most of these species are endemic to Malawi. These species have inferior growth rates and feed utilization compared to exotic species who are legally barred to be cultured in Malawi [6]. The local species can grow with very low inputs, this makes fish farming less intensive, but it affects the final nutrient quality of the fish.

Over the years, many development agencies have joined hands with the government to promote fish farming in order to enhance the welfare of poor farmers [33]. Its positive effects was an increase in fish ponds from less than 100 in the 1960s to over 7000 in 2005 [6].

Despite efforts from the government and non-governmental organizations (NGOs), fish from Malawi's farms are still mainly for household consumption by the farmers themselves and the surplus is sold locally. The government's support for fish farming is challenged by high vacancy rate in the Fisheries Department [41,42]. Additional, most fish farming efforts have failed to continue beyond the funding lifespan of developmental projects by NGOs and development agencies, keeping adoption very low [32]. Indeed, fish production remains lower than other developing countries, which started aquaculture long after Malawi [37]. Despite these setbacks, Malawi fish farming has the potential to improve income and food security [43].

The slow development of fish farming in Malawi has several factors, with institutional failures being a primary cause [41,42]. There have been many initiatives aimed at supporting fish farming, but these did not yield the projected benefits [32]. For instance, restoration of *Oreochromis* spp. stocks (important food fish) in major water bodies [44], has yet to be assessed in terms of impact. On the other hand, Malawi's Presidential Initiative on Aquaculture Development (PIAD) that aimed to develop fish farming sector [45], failed to meet its target of 5000 metric tons of fish by year 2011. Currently, aquaculture production for Malawi is 3600 metric tons per year [5].

3. Conceptual Framework

In order to understand fish production and its interaction with other systems, the elements of food system approach were used [1,46,47]. Furthermore, food security [48], sustainable diets [19,20,49], and vulnerability frameworks [50] were also used to enhance the understanding of the food systems' outcomes and their interaction effect with other aspects like the environment (Figure 1).

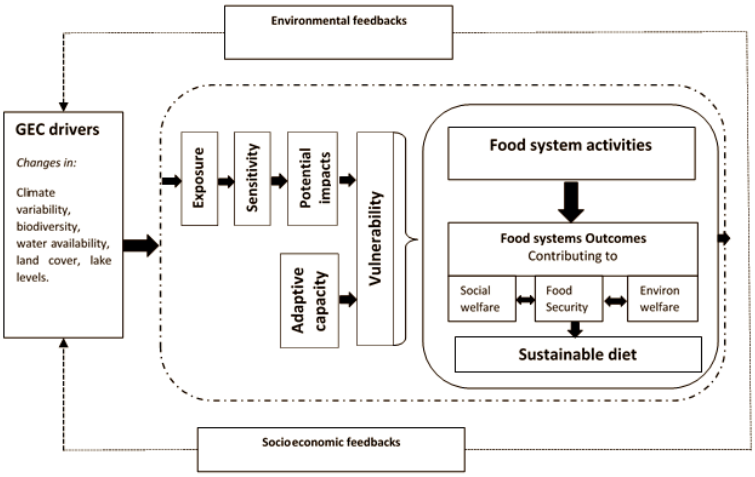

Figure 1. A sustainable food system (adapted from [1,46–48,51]).

A food system is defined as a "chain of activities from the production to consumption with emphasis on processing and marketing and the multiple transformations of food that these entail" [1]. Food systems have been typified by Ericksen [46] as traditional and modern. Malawi fish farming fits well in the traditional category where "the supply chain is short and local, production systems are diverse and vary, labor is family based". Furthermore, the food system concept is part of the systems approach, which open doors with respect to understanding complex interactions that govern a specific behavior towards attainment of food security [46].

Food security is another complex multidimensional concept that this study looked at. Food security is achieved when the following conditions are met "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life" [48]. This concept is dynamic and has three main pillars—namely food availability, food access, and food utilization. Food availability deals with production, distribution, and exchange. Whereas access to food comprised of affordability, allocation, and preference. Finally, utilization consists of three elements—nutritional value, social value, and food safety [46]. Food security is important, but that security needs to be developed in a sustainable fashion [19].

Therefore, the concept of sustainable diets is used in assessing the processes of food production. In order to understand sustainable diets, it is also important to realize factors which affect it, especially in food insecure areas like Malawi. Sustainable diets "are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptance, accessible, economical fair and affordable; nutritional adequate, safe and health; while optimising natural and human resources" [20]. This concept is also complex and multidimensional as it touches many areas and it is difficult to measure and in most cases it is presented as a description of the food system [19]. However, Lairon [52] in applying the concept looked at how food is produced (low input agro-ecological food production); where is food being produced (local production and short-distance

production-consumption nets) and food quality, culinary skills, dietary pattern, and nutrition education as some of the aspects which could be used to describe sustainable diets. Even though Béné et al. [53] showed how fish is important in feeding 9 billion people by 2050, the role of fisheries and aquaculture in sustainable diets is less investigated [18,54].

As much as fish farming has the potential to build food supply resilience, it has also been found to lower resilience in cases where it "relies on terrestrial crops and wild fish for feeds, its dependence on freshwater and land for culture sites, and environmental impacts associated to it" [55]. Therefore, promoting fish farming has to safeguard against such impacts. Other authors found out that despite the increase in global aquaculture production, fishmeal and oil needed in aqua feeds have remained stable—in some cases—it is projected to go down [56]. For Malawi, caution has to be taken because its aquaculture species rely on feed inputs, which compete with humans. However, many fish farmers in Malawi do not feed their fish with formulated diets. Furthermore, these farmers also struggle to feed fish with crop and animal residues due to lack of labor to collect these residues during the main farming season [57].

Despite being lowly intensified, fish farming might also be under similar threats of global environmental changes, which impact both capture fisheries and agriculture. Therefore, application of the vulnerability concept enables an evidence-based assessment which does not only focus on the final outcome but also on causal interactions affecting fish farming. Vulnerability is comprised of three elements—exposure, sensitivity, and adaptive capacity [50]. These components vary based on spatial and temporal scales [58]. However, these components are also affected by socio-economic factors, socio-cultural institution among others [59]. In this study, vulnerability is used to separate different drivers of change like climate and socio-economic transformations [47]. However, since fisheries has been failing to provide enough food due to different changes, and in that case it is considered to be vulnerable [46]. Should that also be the case with fish farming?

This study assumed linkages between environmental degradation [44] and food system activities [1,46,47] which has an impact on food security. This includes social welfare and the environmental security or natural capital which both affect and are affected by food security [48]. This emphasizes the need to move away from just looking at the impacts of climate change on food production to also include how it can reduce the causes of climate change [1].

4. Materials and Methods

4.1. Study Site

The study was conducted in Nkhotakota (Figure 2), a district located on the western shores of Lake Malawi, between two phases (January 2016 to May 2016 and July 2017). Lake Malawi is shared by three countries—Malawi, Tanzania, and Mozambique. Nkhotakota is located in the central region of Malawi and is 200 km North East of Lilongwe, the capital city of Malawi. The district has two climate seasons: the wet season, which spans between November and April; and the dry season that spans between May and October. Nkhotakota's annual rainfall varies between 860 mm and 1600 mm while the average monthly maximum and minimum temperatures are 28.7 °C and 20 °C respectively [60].

The majority of Nkhotakota's inhabitants are small scale fishers [60], who use different types of fish catching equipment and catch different types of fish [61]. However, fish catches in Nkhotakota have been fluctuating and some major species are rarely caught these days [3]. Despite having small land area, the people of Nkhotakota are also engaged in agriculture. On the other hand, big chunks of the land in Nkhotakota is used for sugar cane cultivation by commercial companies and the other parts are reserved for game and forests [60].

Nkhotakota is a climate change hot spot due to global environment changes impacts. For instance in April 2018, there were many flash floods which destroyed crops and property [62]. These were caused by the El Niño-Southern Oscillation (ENSO) circulation patterns [63]. Despite Nkhotakota being a climate hotspot, there is lack of research on how these changes have affected livelihoods of

local communities. Therefore, there is a need to investigate other sustainable livelihood sources that could be appropriate for such communities. Of course, there have been climate related studies on agriculture [64,65] and fisheries [3] in Nkhotakota, but these studies lacked aspects of interaction with other livelihood sources. For instance, Russell et al. [6] reported that Nkhotakota had fish farming activities, therefore it will be important to look at its interaction with agriculture while devising ways of scaling it up as a livelihood source.

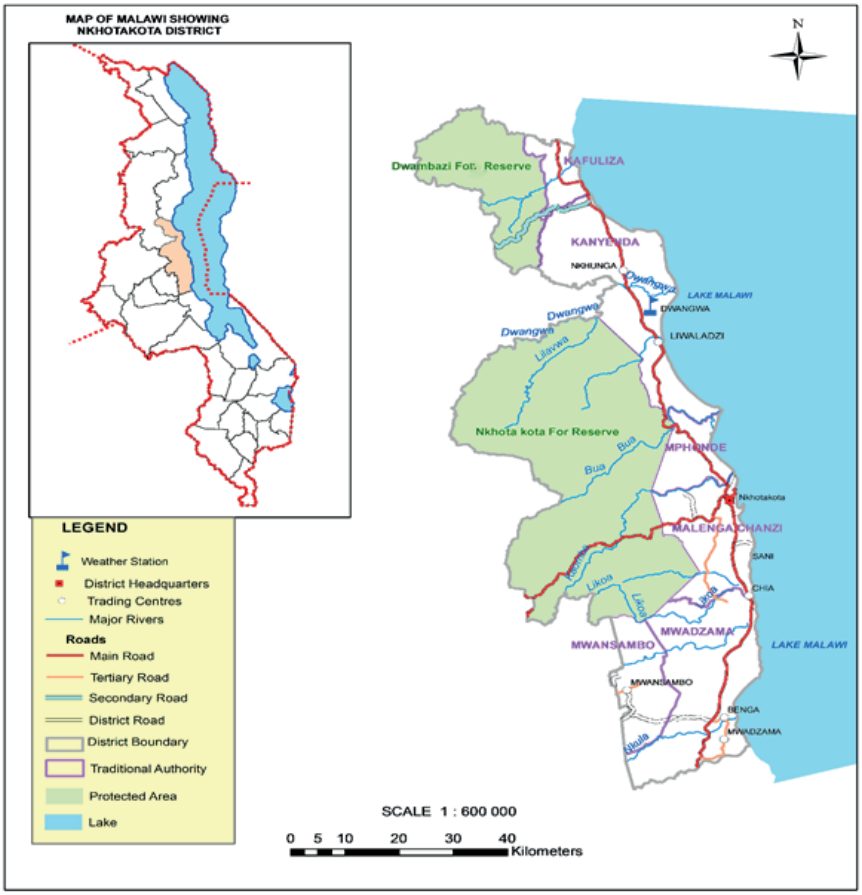

Figure 2. Map of Malawi showing Nkhotakota district and the study area [3].

4.2. Data Collection

To explore the status of fish farming and its suitability as a livelihood source in Nkhotakota, we used mixed sampling methods [66,67] to collect and analyze data. These methods included an exploratory survey, which was conducted to contextualize the research within the study area. During the explorative survey, we visited farming households to appreciate the level of fish farming technologies and facilities in use. Furthermore, we had open-ended interviews [68] with the fish farmers, fish farming clubs, village development committees, fisheries department, and NGOs. This involved asking questions related to: livelihood sources and food security; the status of fishing farming and challenges being faced; common extreme weather events for the area and their impact on livelihoods.

Most of the responses from the exploratory survey were used to develop research tools for the quantitative household survey (Supplementary Materials). We used a semi-structured questionnaire adapted from Andrew et al. [69] to collect information on: household composition and structure; access to and use of land and natural resources; household livelihoods and wealth indicators; food security; fish farming activities; climate change risks; perceptions on climate and ecosystem changes and analysis of adaptation measures to climate change. Forty-seven (47) fish farmers (pond owners) were randomly sampled [70] for household interviews from those engaged in fish farming.

As a follow up to household surveys and exploratory interviews we also conducted focus group discussions and key informant interviews. The participants to these were purposively sampled. This enabled collection of in depth information from a small number of cases carefully selected and fit the phenomena under study through open-ended questions [66,68]. These methods helped to probe the respondents and to interpret data by seeking answers on how and why questions. Ten (10) focus group discussions were conducted with fishers, beach village committees, fish traders, lead farmers, fish farmers, and fish farmers' clubs. These groups were separated by gender to enable women contribute freely to the discussions [29]. Additionally, we also conducted five (5) key informant interviews with extension agents, lead farmers, government officials, and NGOs to understand fish farming. The use of different methods increased the validity and reliability of the findings as it enabled triangulating the sources of information, which provided depth and breadth of the context under study [66].

4.3. Data Analysis

Qualitative data was transcribed, translated to English and then analyzed using content analysis for themes [71]. Content analysis involves coding the data to get initial themes, which are reviewed and named based on data patterns. In order to express the sentiments of different groups of people interviewed, we also used direct quotations in some cases to support the results.

Household survey data was analyzed using descriptive statistics (frequencies, means, range, and proportions). Furthermore, we used inferential statistics (Independent sample *t*-tests at a 5% confidence interval) to test the significant differences between water usage in irrigation and fish farming. We also used Pearson and Spearman correlations to assess factors that affected participation in fish farming. Despite the small sample size for the quantitative household surveys, which could have presented limitations in robust statistical analysis, we used qualitative results to support the outcomes [66].

5. Results

5.1. Context of the Study Area

5.1.1. Socio-Economic Factors

Table 1 summaries the characteristics of the respondents that have implications on achieving sustainable diets from fish farming food systems. The majority (98%) of the sampled respondents were men and these were the ones who owned fishponds. This might entail labor demands in conducting food system activities, land ownership processes, and how the innovations were diffused to the respondents. The results also show that none of the respondents had fish farming as a major food system suggesting that it supplemented other systems like agriculture.

Table 1. Household characteristics as described by respondents in semi-structured interviews (N = 47).

Characteristic		Frequency	Percent (%)
Sex	Male	46	98
	Female	1	2
Marital Status	Married	44	94
	Single	1	2
	Widowed	1	2
	Divorced	1	2
Main occupation	Agriculture	42	89
	Fisheries	3	6
	Hunting	2	4

Source: Fish farming survey data, 2016.

Table 2 shows other socio-economic characteristics of the respondents. The average age of the respondents and time stayed in the area were 43 and 36 years respectively. This suggests that many of the respondents were born in the study area and this affected land ownership, which is one of major factors of food production where food systems activities are conducted.

Table 2. Key farmer attributes as described by respondents in semi-structured interviews (N = 47).

Household Socio–Economic Factors	Sample Mean	Max (min) Values
Age of household head (year)	43	79 (22)
Amount of time stayed in the area (year)	36	77 (2)
Education of household head (year)	5	12 (0)
Household size	4	9 (1)
Household land for farming (m^2)	24,119	93,078 (0)
Household earthen ponds size (m^2)	949	6400 (40)
Assets cost (US$)	132	1356 (1.4)

Source: Fish farming survey data, 2016. US$1 = MKW 733.

The average education years was low suggesting difficulties in understanding the basic biology required in both agriculture and fish farming. These results further showed that the respondents possessed large land holding sizes, suggesting availability of land for agriculture and fish farming. Despite having large land holding capacity, the average household sizes were small. This illustrates low family labor availability for farming activities because farming was not mechanized, but relied on human labor.

5.1.2. Land Quality and Crops Grown

A large proportion (67%) of the land was cultivated and the mean of cultivated land was 12,383 m^2. Table 3 shows land quality as a function of soil quality [69]. Most households (96%) had a field for agriculture, with soil quality ranging from good and excellent. These results imply availability of good quality land for venturing into different types of farming.

Table 3. Frequency (n) of soil quality in the households' arable land as a function of land quality as described by respondents in semi-structured interviews (N = 47).

Soil Condition	Field 1	Field 2	Field 3	Field 4	Field 5
Poor	12	4	0	0	0
Good	32	22	11	3	2
Excellent	1	1	1	0	0

Source: Fish farming survey data, 2016.

The respondents practiced mixed cropping and the proportion of the total farmed area under different crops was: summer maize (39%), winter maize (8%), cassava (15%), rice (12%), sweet groundnuts (12%), potatoes (6%), pigeon peas (6%), and vegetables (2%). Of these crops, rice was the only crop which was grown for sale while the rest were for household consumption. At the same time, processing of the harvest did not involve any value addition. The high diversity of crops grown suggests well balanced diets and good nutrition in the study area. The growing of many crops also could be an indication of livelihood diversification in cases where other crops fail. The many crops also entail a good pool of agricultural residues that could be used to fertilize agricultural fields or fishponds. Recycling of wastes further entails how sustainable the food systems were.

5.1.3. Water Availability

The growing of many crops could entail availability of water and land to drive the food system. Furthermore, water availability is both crucial in agricultural and fish farming food systems just like land. The study showed that all respondents had access to water for agriculture and fish farming. The water sources included: furrow from a river (40%), ground water seepage (30%), furrow from a spring well (17%), and from a shared irrigation furrow (4%). However, water flow was variable due to less rainfall (57%), evaporation (18%), low stream flow (11%), seepage from furrows (11%), and competition between users (3%). The competition in water usage suggests that food production did not follow the sustainable diets concept.

During the qualitative interviews when we probed on the water usage competition from a focus group discussion at Site A on 15 May 2016. We were informed that, due to extensive rice production and the need for each farmer to maximize rice production, some farmers had channeled the water to the rice fields without considering other farmers who also wanted the same water for farming. However, keeping stagnant water in rice fields also increases production of methane which is a greenhouse gas that influences global environmental changes.

While that could be an isolated case which might not reflect the entire study area, another key informant interviewed at Site B on 31 March 2016 had to say this "*I have plenty of water and land for any land based farming operation, however the only lacking thing is capital to expand my farming activities*".

The annual water availability showed significant differences between water usage for irrigation and fish farming (t (11) = −13.4, $p < 0.001$). Water flow for irrigation and fish farming decreased between June and January (Table 4). Still, the majority of respondents (87%) cited having enough water to support expansion of fish farming and agricultural activities. There was equal preference for expanding agriculture through irrigation and fish farming. This suggests how these food systems were important to the respondents' livelihoods, despite none of them citing fish farming as a major food system.

Table 4. Frequencies (n) and proportions (%) of annual water access for irrigation and earthen fishponds as described by respondents in semi-structured interviews (N = 47) between June 2015 to May 2016.

Month	Irrigation		Earthen Ponds	
	No Flow	Flow	No Flow	Flow
June	18.5	81.5	16.3	83.7
July	18.5	81.5	18.6	81.4
August	25.9	74.1	23.3	76.7
September	33.3	66.7	39.5	60.5
October	44.4	55.6	41.9	58.1
November	40.7	59.3	39.5	60.5
December	22.2	77.8	30.2	69.8
January	22.2	77.8	14.0	78.7
February	18.5	81.5	7.0	93.0
March	18.5	81.5	9.3	90.7
April	22.2	44.7	11.6	88.4
May	18.5	81.5	11.6	88.4

Source: Fish farming survey data, 2016.

5.1.4. Livestock Ownership

Water availability also determines types of livestock suitable for the study area. Table 5 shows livestock ownership in the study area. Livestock were used to provide food and income to the respondents. Although water was available, the results revealed that the study area does not have many livestock types and some households did not own livestock. Even though there were less livestock, the majority (72%) of the respondents had access to grazing lands. The grazing lands belonged either to the community (46%) or individuals (54%). These results have implications on the availability of cheap animal protein sources and animal wastes being generated for agricultural fields and fishponds fertilization. The low number of livestock also meant that low production of greenhouse gases that has an impact on global environmental changes.

Table 5. Livestock ownership (mean, maximum, and minimum) as described by respondents in semi-structured interviews (N = 47).

Livestock	Mean	Maximum	Minimum
Cattle	0.23	6	0
Goats	2.21	11	0
Sheep	0.4	11	0
Pigs	0.6	11	0
Chicken	6.8	55	0

Source: Fish farming survey data, 2016.

Having noted the importance of the livestock component in both agricultural and fish farming food systems, we further probed during the focus group discussions on the reasons why the area had few types of livestock and what was the role of livestock in their lives. It was noted that some types of livestock for example were not kept due to religious beliefs as the study area had a large number of Muslims. Furthermore, the study showed that small stocks (goats, chicken, and sheep) were easy to keep because they did not require many production inputs. However, these were also suitable for very hot weather as perceived in the study area. While investing in cattle was hard for the respondents due to lack of extra income to purchase the livestock and to pay for labor services of cattle herders.

5.2. Fish Farming Food System

5.2.1. Fish Farming Objectives and Division of Labor

The study showed that the main objective for fish farming by all respondents was mainly for food with a possibility of selling surplus fish produced. The respondents were first involved in fish farming by self-motivation (54%), often by fish farming project incentives (39%) and occasionally through inheritance (7%). The fish farming food system's activities were dominated (92%) by household heads who happened to be men.

Most respondents (83%) were still involved in fish farming 20 years after adopting the innovation. However, some respondents (17%) had stopped fish farming due to no source of fingerlings (39%), low water levels (35%), lack of profits (13%), and flooding which damaged their ponds (14%). These results reveal challenges with the food system activities. Whereas low water levels and flooding were related to the effects of global environmental changes. However, the identified bottlenecks for the fish farming food system activities offered business opportunities for potential investors in supplying fingerlings and fish marketing solutions.

During the qualitative interviews with inland fishers and the beach village committees on why they were not involved in fish farming, one participant cited that:

> We are everyday cash people with exceptions when our fishing nets are damaged or if the south easterly winds are persistent. We do not have the patience of waiting for more than six

> months for the fish to mature in fishponds. It is also better to venture into agriculture, because it is very difficult to be sure, if our fish are in the ponds or they have been either stolen or died. Secondly, fish farming requires a lot of education which most of us do not have.

This suggests that adoption of fish farming by such groups of people might not be easy because of such perceptions.

5.2.2. Organization of Fish Farmers

Most fish farmers (81%) were members of fish farming clubs. Fish farming clubs are comprised of farmers who own at least a fishpond and are hardworking, trustworthy, reside in villages closer to each other, and have the ability to pay entry and annual subscription fees. The clubs have governance structures that are elected annually. Furthermore, the clubs were entry points for any fish farming related development initiatives. The benefits of joining a fish-farming club were easy access to: loans, extension services and advice, fish markets, labor when digging the ponds, cleaning, feeding, and harvesting. While for old club members, the club was a platform for sharing lessons learned in fish farming. These results suggest that even if farmers had individual ponds, but the food system activities were influenced by their group dynamics.

During a focus group discussion with a fish farming club members, the governance committee emphasized that:

> Being a member of the fish farming club has improved our livelihoods by expanding sources of income and food. The income has also enabled timely payment of school fees for our children and we expanded our farming activities.

5.2.3. Land Allocation to Ponds and Cost of Digging Ponds

The fish farmers had variable fishpond sizes. The majority (72%) of the fishponds were less than 900 m^2 while some (21%) ranged between 1000 and 6400 m^2. This also applied to the number of fishponds per farmer, with some (34%) having two ponds, others (15%) having three ponds, and half (51%) of the respondents having one pond. In comparison with agricultural food system, the total land invested in fish farming was 13 times less. The average cost (US$54) for constructing a fishpond using combined family and fish farming club labor was six times less than those who engaged hired labor (US$341). Most of these ponds were self-constructed (57%), inherited (25%), project constructed (11%), and constructed with paid labor (2%). These fishponds were constructed between 1989 and 2016 and the common culture methods were monoculture (75%) and polyculture (25%). The culturing methods illustrated a certain level of sustainability and maximized usage of production inputs within the different food systems in the study area.

5.2.4. Common Fish Species Stocked

The common cultured and preferred fish species were: *Oreochromis shiranus* (54%), *Oreochromis karongae* (26%), *Tilapia rendalli* (10%), and *Clarius gariepinus* (10%). These species were preferred because of having: good flavor, simple diet, early maturation, fast growth rate, low mortality rate, and high reproduction rate. Despite accessing fish fingerlings from other farmers, self-production, NGOs, and the Fisheries Department, the respondents had challenges in accessing fingerlings for all the preferred species. Only one farmer was producing fingerlings in the study area and in 2015, he sold 300 fingerlings to fellow farmers at US$0.04 each.

5.2.5. Fish Feeding

Fish feeding is an important food system activity. Therefore, stocking quality fingerlings without feeding them could have negative effects on the final product. The majority of respondents fed their fish with maize bran (84%) and some with rice bran (9%). On the other hand, some (24%) used cassava wastes. Fishponds' primary productivity was also boosted with organic manure (77%). The manure

sources were goat (61%) and chicken (12%) droppings. In addition to crop and animal by-products, some respondents (6%) also provided mineral premixes to their fish. These feeding schemes suggest that sustainable ways of recycling residues were being practiced. Despite less mineral supply to the fish, none of the farmers cited fish-disease outbreaks. These results further illustrate that fish health was not affected by a lack of formulated diets or any other supplementary feeding.

5.2.6. Fish Harvesting

When harvesting fish, all farmers did not drain the ponds due to water problems. Fish were harvested at different times. Half of the farmers (51%) harvested the fish after a complete growing cycle (6–9 months); while others (24%) had no specific harvesting roster, some harvested monthly (22%) and weekly (2%). These methods suggested that different fish sizes were harvested as a response to either market demand or household consumption or different stocking times or different maturation times for the cultured species.

5.2.7. Fish Marketing

For the question "Does the price that you receive for the same weight of small and large fish differ when you sell your fish?" the responses were yes (64%), no (7%), and I do not know (27%). The respondents' fish sales between 2011 and 2016 showed that most of the fish produced were sold at the local market. The reasons given for selling the produce at a local market were proximity to farm (69%), direct cash payment (17%), better prices (11%), and encouragement from NGOs (3%). The distances to the local markets ranged from one to five kilometers and the average transportation cost to the nearest market was US$0.30. Despite selling fish locally, the fish farmers also suffered multiple problems: low fish price (69%), long distance (8%), late payments (3%), and conflicts within the farming club (3%). Selling fish locally entailed improved sustainable diets by optimizing taste and flavor. The average fish price per kilogram between July 2015 to June 2016 was US$0.60. The outputs from the fish farming food system were fresh fish and fertilized water used for agricultural activities. Furthermore, no value addition—i.e., packaging or preservation of the fish—was done, suggesting that the fish retained all their nutrients. As shown from the results, by the time fish were harvested the farmers might have consumed or sold most of the fish. This further illustrates availability of animal protein to the households and their kinship involved in fish farming.

5.2.8. Fish Farming Cost Structure

The major costs related to fish production were feed (86%), labor (9%), construction and maintenance of the fishponds (5%). Evaluating these costs was partially done by examining fish farming records kept by half of the fish farmers. However, the majority (89%) of the records were poorly maintained with a lot of missing information. This might be a result of respondents' low education levels. These results suggest that calculating profitability could pose a challenge due to a lack of records, however, the main purpose of fish farming was not entirely profit oriented.

5.2.9. Fish Farming Technologies Adoption and Dissemination

Despite low education levels and lack of proper record keeping, the respondents had adopted many fish farming technologies. These included: integrating agriculture and fish farming, direct feeding with formulated diets, direct feeding (maize bran, cassava wastes, and vegetables), cleaning the ponds after harvest, use of polyvinyl chloride (PVC) pipes as water inlet and outlet, use of ash as a buffer system, and using fast growing fish species like *O. shiranus*. Diffusion of fish farming was passed through multiple channels, but most respondents (67%) accessed it from extension agents. The average contact time of farmers with extension agents was 1.66 times per month. To supplement visits by extension agents, lead farmers were also acting as role models to other farmers. Lead farmers advised fellow farmers on fish production and securing better markets. About half of the respondents (45%) had been in touch with a lead farmer. Lead farmers were selected based on: nomination and voted

by fellow farmers at the fish farming club; possession of a fish farm and being knowledgeable about fish farming; good level of education and training in fish farming. During key informant interviews, extension agents cited facing the following challenges:

> … there is lack of funding for us to do activities such as offering business and general fish farming lessons; there is no transportation for us to travel long distance to the fish farmers from where we are based; and we are few extension workers to cover many potential and existing fish farmers.

These results suggest that the extension agents were not motivated to work hard as their working conditions were poor. During another focus group discussions, fish farmers cited the following on how dissemination of fish farming information have improved their fish farming:

> Much as we want to be visited more often by the agents. However, with the little information they gave us we managed to generate a lot of profits, what more if we had more information.

5.2.10. Factors Affecting Fish Farming Participation

Table 6 summarizes factors which affected fish farming. Water availability, money spent on non-staple foods, area planted with cassava, buying staple food in December, and the amount of fish partially harvested at one time increased participation in fish farming. Whereas operating a bicycle taxi, being a former fish farmer, amount of compost and rice bran applied to the fishponds, and providing casual labor in October reduced the probability to participate in fish farming. These results suggest that most of the significant factors had a direct implication on the productivity of the food system.

Table 6. Factors affecting the current fish farming participation (N = 47).

Variable	Correlation Coefficient (r)
Bicycle taxi	−0.33 **
Participated in fish farming before and currently not	−0.88 **
Amount of compost applied in ponds	−0.38 **
Amount of rice bran applied in ponds	−0.35 **
Participation in Ganyu in October	−0.29 *
Buying staple food in December	0.37 **
Water availability	0.51 **
Money spent on other foods not staple food	0.45 **
Amount of cassava planted	0.38 **
Number of fish harvest at one time during partial harvesting	0.32 **

Source: Fish farming survey data, 2016. *, ** Pearson and Spearman correlation, significant at 5% and 1% respectively.

Furthermore, the qualitative interviews also revealed some factors, which might have influenced participation in fish farming. During the focus group discussions and key informant interviews, we gathered the following overview on factors affecting fish farming participation:

> … yes we are fish farmers, but we also have successes and challenges when culturing the fish, the important successes include availability of fish throughout the year, we are not worried or concerned by hash weather conditions affecting the fishers at the lake; furthermore, we can irrigate winter crops with the water from the ponds. Our challenges include in some cases, drying up of the ponds due to poor workmanship during construction and extreme hot temperatures; sourcing of quality fish seeds is not easy as certified hatcheries are very far away; and cheap formulated diets …

On the other hand, we also provide a summary of a key informant interview with a female fish farmer.

> … fish farming is good because we don't have to worry about food throughout the year, however as a woman I am challenged because fish farming is labor intensive, especially during pond construction and harvesting; therefore, I have to hire paid labor …

The results for the qualitative and quantitative interviews have revealed multiple factors affecting the fish farming food system at production level. Despite the differences in the significant factors between the two methods, all the factors are important in enhancing productivity of the food system. The study can only attribute such disparities to a small sample size for the quantitative part, which was however supported by qualitative interviews.

5.3. Effects of Perceived Extreme Weather Events on Fish Farming

The study observed through qualitative interviews that some extreme weather events were directly affecting fish farming. Those observations were confirmed through household survey, where most fish farmers (89%) experienced significant changes in weather patterns between 2000 and 2016, compared to the 1980s and 1990s. The extreme weather events included increased incidences of drought (47%), late rainfall (40%), floods (6%), dry spells (4%), and extreme temperatures (2%). However, in the past five years (2010–2015), some respondents (58%) were exposed to these events in 2015 compared to 2% in 2013. While in the last 20 to 30 years, the exposure to rainfall has been erratic (37%), late onset (41%), poor distribution (20%), and early onset (2%).

The study revealed that, in general, the common impact of the extreme weather events included crop damage, livestock loss, loss of biodiversity, and low fish catches. Whereas the specific effects to fish farming observed by the majority (75%) of fish farmers included death of fish, low fish yields, drying of ponds, high water temperatures, and lack of natural food for the fish. These results suggest extreme weather events are a force to reckon in fish production.

5.4. Food System Outcome

Although the study has revealed that both fish farming and agricultural food systems are facing challenges, however these are better placed because the farmers can influence the production unlike in the capture fisheries ecosystem. The main outcome of these food systems was supposed to be food security. Therefore, in assessing the annual availability and utilization of food consumption by the respondents, the study showed that most (60%) of the respondents had enough food, whereas some (7%) lacked proteins only, some (13%) also had no staple food and some (20%) did not have enough food throughout the year (Table 7). These results reflect that being involved in either fish farming or agricultural food systems did not always result in producing enough food for consumption.

Table 7. Proportions (%) of household food sufficiency (N = 47) between June 2015 to May 2016 as described by respondents in semi-structured interviews.

Month	Enough Food	Lack of Protein Only	No Staple Food	No Food	Buy Staple Food	
					Yes	No
June	78	4	9	9	15	85
July	83	4	4	9	13	87
August	81	2	6	11	17	83
September	77	2	64	15	21	79
October	68	15	0	17	32	68
November	62	4	19	15	34	66
December	23	6	28	43	53	47
January	34	6	26	34	64	36
February	26	6	32	36	72	28
March	47	11	17	26	45	55
April	72	13	2	13	17	83
May	72	15	4	9	17	83

Source: Fish farming survey data, 2016.

However, the annual food availability varied between the main foods groups (proteins and carbohydrates). For instance, lack of proteins within the year ranged from 2% to 15%. This might be because of fish farming adoption, as the respondents did not have challenges in accessing proteins. The results also reveal that the critical months where households lacked food were between December and March. During these months between 44% and 72% of the households bought staple foods.

5.5. Household Income and Expenditure

Table 8 indicates that a large proportion of income was generated from crop sales (60.1%) and most of it was spent on food (51%). Despite fish sales contributing (10%) to the annual income, the respondents also bought fish for consumption. These results suggest that income for the respondents was centered on the agricultural and fish farming related food systems.

Table 8. Annual household income and expenditure proportions for the study respondents (N = 47) between June 2015 to May 2016 as described by respondents in semi-structured interviews.

Income	Mean %
Formal employment	0.5
Part time employment	1.1
Business (artisan, shop, bicycle taxi)	0.5
Casual employment (off farm)	3.8
Seasonal farm employment	9.1
Remittances	5.5
Crops sales	60.1
Livestock sales	6.8
Fish sales	9.5
Rents	1
Other sources of income	2.1
Total	**100**
Expenditure	
Education	11.4
Transport	3.6
Food consumption (maize, rice and cassava)	25.0
Food consumption (fish)	4.8
Food consumption (other foods)	21.2
Building materials	3.1
Clothes and blankets	10.1
Furnishing and domestic utensils	4.0
Tools and inputs for productive activities	11.0
Luxuries	2.34
Labor	2.5
Rents	1.0
Total	**100**

Source: Fish farming survey data, 2016.

6. Discussion

6.1. Socio-Economic Factors

Socioeconomic factors are an important aspect of any food system's outcomes. These factors also drive the necessary feedbacks and interactions with other components of the food system. By the respondents not having their main occupation as fish farming it had some implications on the study area's food system. Furthermore, despite all the respondents owning fishponds and having water, they were not full time fish farmers. The fish food system was dominated by men (98%), and this suggests labor intensive activities, especially during constructing of fishponds, fish harvesting,

and pond cleaning. Although these results are consistent with other studies in Malawi [43], it was surprising that few women were involved in fish farming despite being custodians of the land due to a dominant matrilineal system [72]. However, access and ownership of farming land in the study area was not a problem. This could be attributed to the household head's age and the amount of time having stayed in the area. In other areas in Malawi, land can be accessed through either inheritance or granted by local leaders or purchased [73]. The majority of the fish farmers were married; and being in such a marital status might have a potential to improve labor availability for farm activities even though their household sizes were small. Another factor, which has an impact on farming activities, is level of education [74]. In this study, the average level of education was very low. This might have a negative impact in adoption of innovations like fish farming which represents a complex food system.

Complexity of fish farming could be the reason the majority of the respondents were into agriculture. This was also confirmed in the qualitative interviews, and is reflected in the major income sources. However, the low proportion of fish farming incomes to the total annual income were within the range (1–17%) that has been reported for Malawi [69]. However, these results might not be good enough to encourage adoption of fish farming as a business [38,69] but as a necessary food system in enhancing food security.

6.2. Fish Farming Food System

Although fish farming contributed low income to the respondents. Its adoption was consistent to findings reported by Hecht and Maluwa [41] and Russell et al. [6] in Malawi and Brummett et al. [75] in Cameroon. These results indicate that no new development players have been promoting fish farming except for the government and NGOs. This might be attributed to some adopters discontinuing it due to lack of inputs to enable them to execute several food system activities.

Lack of inputs like fingerlings could be a reflection of small sized fishponds, despite having large land holding capacity. The mean sizes of the earthen ponds were lower than the recommended size for maximizing production (1000 m^2) in Malawi [76]. These results reveal opportunities to use fingerlings from the wild as the farmers are closer to Lake Malawi than where certified hatcheries are located. Use of fingerlings from the wild has been reported to be profitable [77].

Another trait of importance which could lower mortalities is high disease resistance in the cultured species despite no mineral supplementation. This could be attributed to species hardness [32] and low stocking densities [78,79] among other factors not explored in this study. On the other hand, one of the cultured species (*Tilapia rendalli*) can grow with less food, making it a candidate for fish farming to farmers who cannot afford feeds [80]. This could also be true for the other species cultured in the study area [32].

Culturing of different species could be the reason farmers had varied harvesting times, while this shows these species were sustainably using different food available in pond environment [81]. This also could be an indication that farmers were using their farms, as safety nets when food and income were needed urgently [69]. Although this practice makes it difficult to calculate profits, it could be viewed as a sustainable livelihood strategy. Partial harvesting also enabled the fish farmers to supply different market segments with different fish sizes. However, leaving fish to continue growing entailed incurring more production costs [82], as revealed in this study. This could be true if animal and crop residues applied to the ponds were being bought or costs were incurred in transporting them from their source. The use of animal wastes improves pond fertilization more than crop residues [83].

High fish farming costs could be also a reflection of the process of diffusion of innovation. The drivers of such a process are extension agents [74], and with less visits by extension agents, high costs are expected. Furthermore, packaging of extension messages plays a big role in adoption of an innovation [29] and it is affected by the level of education. Some studies have recommended targeting extension support to certain fish farming food system activities, like fingerling production compared to table size fish production [84]. Despite the absence of formal fingerling producers in the

study area, this study recommends providing extension services to both fingerling producers and table-sized fish farmers.

Fish farming participation has also affected agricultural food systems. For instance, increasing the amount of land under cassava cultivation improved fish farming participation. This could be attributed to cassava not requiring many inputs compared to other crops, like rice and maize, grown in the study area [85]. An input like labor could be channeled towards fish farming operations, which is laborious.

There were also other factors, which affected fish farming participation. For example, having income from the bicycle taxi reduced farmers' motivation to farm fish. This entailed having more purchasing power to buy food and fish from other farmers. While contrary to the tenets of earthen pond fish production, adding residues (compost and rice ban) reduced fish farming participation [62]. These results might be a reflection of competition for use of these residues in the agricultural fields as a fertilizer because the respondents had agriculture as their main occupation.

Even though some factors were supposed to influence fish farming participation, this was not the case. Factors like extension agent visits, level of education, land holding size, age, and gender are known to significantly influence fish farming participation. This could be attributed to the study sample size, which was small compared to other studies, which found these variables to be significant [40]. Another explanation of the small sample size could be related to social structures and perceptions of people around the study area regarding fish farming as they are close to the lake where they could get fish with ease even though the catches had gone down [3].

6.3. Impact of Extreme Weather Events on Fish Farming

The study revealed that the respondents perceived extreme weather events to affect fish farming food system. These events have the potential to directly affect food systems and related socioeconomic factors of the respondents, which again drive the food system [47]. The extreme weather events experienced revolved around rainfall and temperature, these results corroborated those of Limuwa et al. [3]. These events are consistent with Kolding et al. [86], who reported that sporadic rainfall patterns are the main driver of environmental changes for many regions in Sub Saharan Africa where Malawi is located. Furthermore, Malawi's rainfall pattern has been showing increased annual variations [31]. Nicholson et al. [30] also noted reduced rainfall in mid-February for Malawi. This might have an impact on agricultural food systems [87] on which fish farming directly relies upon [88–90]. Our results on negative effects of extreme weather events in fish production corroborated with Faruque and Kabir [91]. Such impacts of extreme temperatures offer opportunities to conduct selective breeding for increased temperature tolerance. Whereas raising fishpond dykes could mitigate floods as perceived in the study area [92].

6.4. Food System Outcome

Even though the fish food system is challenged by inputs and weather related events, the respondents had diversified their livelihood sources through fish farming. This was however not enough because they were still food insecure (availability and access), for all food groups between the months of December and March. These results are consistent with GoM [5]. The high availability of protein in the study area might have been supplied through either livestock or domesticated fish or fish from the lake and could be an indication of sustainable diets [52]. However, the study did not quantify other aspects of food utilization like social value and food safety. On the other hand, the lack of staples in the study area has a direct implication on human body energy from the carbohydrates needed for labor intensive farm activities [93]. Lack of staple foods in some months was contrary to diversified crops grown in the study area, but it reflected mechanisms to safeguard against food insecurity [94]. Different crops have different growing requirements and if one crop fails, other crops provide the needed food supply—for instance, crops grown in the area, such as cassava, which is drought tolerant, and soybeans and groundnuts, which do not require extra costs in buying fertilizers because they can

fix nitrogen in the soil [85]. Despite diversified crop production, the study area had few types and low numbers of livestock. These results are contrary to Andrew et al. [69] who attributed having few livestock to lack of grazing land because of high population densities. While this might be true to other areas, the study could attribute high population of small stocks to the climate of the area [95]. However, low numbers of livestock could lead to sustainable diets as it decreases greenhouse gas production, which could increase global warming because livestock produce methane gas [96].

In assessing the fish farming food system and its relationship with the agricultural food system, the study reveals that fish production did not fully result in realization of sustainable diets [52], although it improved food availability and utilization through animal protein. This could be attributed to the competition for production inputs, which existed between agricultural and fish farming food systems.

7. Conclusions

Fish farming food system is important as it provides animal source proteins throughout the year. However, this study has revealed that all the respondents did not consider fish farming as their main occupation. Furthermore, fish farming activities were biased towards men. The fish farmers' education and household sizes were low. The fish farming food system was faced with production challenges—especially accessing fingerlings, formulated feeds, and extension services—even though the fish farmers had access to water and land. Not everyone had food to last them throughout the year and this created the need to intensify fish farming. Weak synergies existed between fish farming and agricultural food systems. Therefore, affecting bio-resource flows between these two systems, as earthen fishponds depended on agricultural residues for their natural productivity. Despite the farmers practicing mixed cropping, the recycling of agricultural wastes in fishponds was also affected by few types of livestock and the competition for the same wastes as a source of fertilizer to crops. Another competition existed for water usage in rice fields between the farmers. These competitions had an impact in attainment of sustainable diets.

Fish farming was also affected by extreme weather events. These events perceived by farmers offer room for practicing adaptive management. For instance, breeding fish for extreme temperature tolerance and early maturing fish strains. Although progress of aquaculture development in Malawi is being made, there is a long way to go before it can be considered successful. This is the case because these pre-existing bottlenecks reported more than 10 years ago are still persistent [6]. Furthermore, the results also suggest the need to strengthen the supply chain by the government or offer business opportunities in food system activities such as fingerling and feed production and supply. Therefore, fish farming is not an illusion as it might provide supplementary livelihoods to inland fishers, but this development reliant upon improving the operational environment with more easily accessible inputs.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/5/1453/s1, Household survey questionnaire.

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Paper IV

Limuwa, M. M. & Sjaastad, E.O. Development initiatives, Livelihood Assets, and Adaptive Capacity among Lake Malawi Fishing Communities (*Manuscript*).

Development initiatives, Livelihood Assets, and Adaptive Capacity among Lake Malawi Fishing Communities

Limuwa, M.M. and Sjaastad, E.O.

Abstract

Enhancing adaptability may be critical to protecting and improving the livelihoods of rural households vulnerable to climate change. We conducted a study on the western shores of Lake Malawi to assess the impact of development initiatives on adaptive capacity. Groups of initiatives examined were directed towards health care, formal credit, infrastructure, employment, and improved food production and natural resources management. Adaptive capacity was articulated as a function of the five groups of capital of the Sustainable Livelihoods Framework. The study revealed that only a third of respondents had benefited from various development initiatives. Adapative capacity was slightly higher among non-beneficiaries, but not significantly different from that of beneficiaries. Compared to non-beneficiaries, adaptive capacity was significantly lower among beneficiaries of credit access while significantly higher among infrastructure beneficiaries. A positive correlation between adaptive capacity and net income was found. Adaptive capacity was lower but more equally distributed among beneficiaries than among non-beneficiaries. The results also suggest that development initiatives may have beneficial effects on adaptive capacity but that these effects may be disguised by a selection of beneficiaries that favours those with low capital endowments.

Key words: Development initiatives, adaptive capacity, Malawi, Sustainable livelihood framework, climate, fisheries, agriculture.

Introduction

Global environmental change poses challenges especially for countries whose economies depend on climate sensitive natural resources (Adger *et al.* 2005; Agrawala & Van Aalst 2008; Allison *et al.* 2009). Malawi has recently experienced an increase in extreme weather events, causing damage to infrastructure and loss of livelihoods (Pangapanga *et al.* 2012; Mwanza 2018). These losses are most keenly felt by poor and vulnerable segments of the population.

A large proportion (> 80%) of Malawi's rural population could be vulnerable (GoM 2017), in part because of precipitation that does not match water demands for most agricultural activities (Shongwe *et al.* 2009; Ngongondo *et al.* 2011; Simelton *et al.* 2013; Nicholson *et al.* 2014). In addition to climate-related challenges, the agricultural sector is also impacted by post-harvest losses, low diversification, small land holding sizes, land degradation, persistent pests and diseases, low market prices, and lack of investment in research and extension (GoM 2017). Even though agriculture is the economic backbone of Malawi (GoM 2016), it is failing to offer sustainable livelihoods to many poor households, leading to cyclic migration between different livelihood sources such as agriculture and fisheries (Mvula 2002; Ellis *et al.* 2003; Chidanti-Malunga 2011; Lunduka *et al.* 2013; Nagoli *et al.* 2017; Limuwa *et al.* 2018a).

Malawi fisheries have historically cushioned the impacts of low agricultural productivity (McCracken 1987; Chirwa 1996; Haraldsdottir 2002). However, Malawi's fish catches have been decreasing, due to low water levels, falling water quality, as well as weak enforcement of regulations and consequent overfishing (Mkanda 2002; Banda *et al.* 2005; Tweddle *et al.* 2015; Hara & Njaya 2016; Nagoli 2016). Low fish catches reduce the opportunities that fisheries would offer as an alternative livelihood source to continued low agricultural production.

Challenges posed by fisheries and agriculture have led to new strategies, some of which are unsustainable. For example, reduced mesh sizes have led to increased catches of immature fish (Mvula 2002; Jamu *et al.* 2011; Limuwa *et al.* 2018a). In agriculture, on the other hand, there has been an increase in intensification methods through climate smart agriculture and use of drought-tolerant and early-maturing crop varieties (Ngwira *et al.* 2013; Thierfelder *et al.* 2013; Fisher & Snapp 2014; Ngwira *et al.* 2014). However, not all vulnerable farmers and fishers can afford to make such technological switches because they involve time and financial investment (Holden *et al.* 2017; Maguza-Tembo *et al.* 2017).

Development initiatives implemented by state and non-state actors may potentially reduce the vulnerability of local communities (Adger *et al.* 2005; Agrawala & Van Aalst 2008; Barnett 2008; Lamhauge *et al.* 2012; FAO *et al.* 2016). These initiatives have the potential to improve general welfare of households from multiple stressors, including extreme weather events (Leichenko *et al.* 2010; O'Brien 2012). Assessing the impact of such initiatives can provide relevant information for efforts to reduce vulnerability of local communities.

This paper evaluates the impact of development initiatives in building adaptive capacity of communities along the shores of Lake Malawi. We ask: who benefits from these initiatives? Which of these initiatives possess potential in terms of enhancing adaptive capacity? And how does adaptive capacity relate to net income and income distribution? We also discuss the problem of targeting and selection bias that invariably attends an analysis of development initiatives using cross-sectional data.

Adaptive capacity, livelihoods, and development initiatives

Adaptive capacity is the ability of a system to adjust to stressors and reduce adverse effects or take advantage of beneficial effects (McCarthy et al 2001). Adaptive capacity is also one of the three main elements within the Intergovernmental Panel on Climate Change's (IPCC) conceptual framework for vulnerability assessment. The other two elements are sensitivity and exposure. Compared to these two elements (exposure and sensitivity), adaptive capacity is easier to influence and deal with (Smith *et al.* 2003). However, the IPCC's Fourth Assessment Report (FAR) identifies limits and barriers to adaptation such as physical and ecological limits, technological limits, financial barriers, informational and cognitive barriers and social and cultural barriers (Solomon *et al.* 2007). Adaptive capacity depends on interaction among different

variables that act simultaneously in a dynamic context and reflect strategies, capacities, and assets available to households for coping with changes and disturbances (Smit *et al.* 2001). Because different communities face different challenges with respect to climate change, indicators of adaptive capacity must be context-specific, generally negating comparison across different studies (Adger *et al.* 2007; Williamson *et al.* 2012). Beyond evaluation of individual determinants as stated in the IPCC's FAR (Smit *et al.* 2001; Adger *et al.* 2007), adaptive capacity can also be assessed using outcome proxies, assuming adaptive capacity is correlated with specific social and economic outcomes. However, interpretation of such proxy indicators is not straightforward (Williamson *et al.* 2012).

The community capacity approach advocates for access and ownership of assets as focal points for adaptive capacity, with strong linkages to the five capitals in the Sustainable Livelihoods Framework (SLF) (Scoones 2009; Williamson *et al.* 2012). In societies that depend on climate-sensitive livelihoods like agriculture and fisheries, adaptive capacity can be estimated as a function of the different assets that households possess (Gbetibouo & Ringler 2009; Nelson *et al.* 2010b). When changes occur, households with a better portfolio of assets are in a better position to adapt compared to those without (Brooks *et al.* 2005). Diversification decreases the risk of livelihood failure by spreading income across more than one source (Ellis 1998). The linkage between adaptive capacity and household assets is mapped through the use of SLF (Figure 1).

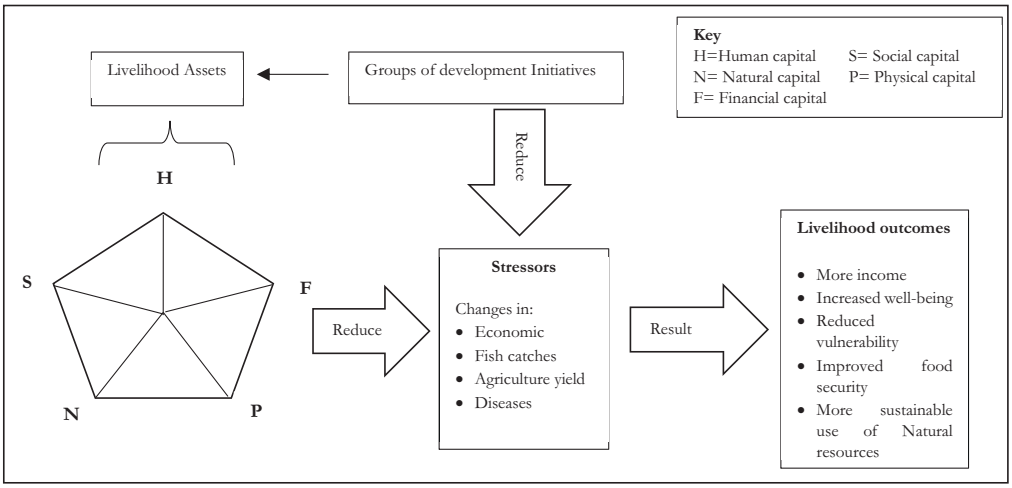

Figure 1: The Sustainable Livelihood Framework – Adapted from (Scoones 1998).

These capitals are natural, human, social, physical and financial. Access to assets is enabled or hindered by processes, structures and external factors that are outside the control of the household, referred to as the vulnerability context, comprising trends related to climate, conflicts, resource stocks, population density, technology, politics, and economics (Carney 1998). The framework regards the asset status of poor individuals or households as fundamental to understanding options open to them (Ellis & Freeman 2005).

The SLF has been used as a tool to understand the role and diversity of fishers and their livelihoods in the context of factors that make them vulnerable (Allison & Ellis 2001; Allison *et al.* 2002; Allison & Horemans 2006; Andrew & Evans 2011).

Furthermore, this framework provides a logical foundation for the linking of development initiatives and adaptive capacity. Development initiatives take many forms and may have any number of objectives; enhancing the capacity to adapt to climate change will only occasionally be among them. However, insofar as such initiatives have beneficial effects on household capital – intentionally or otherwise – they may serve to improve adaptive capacity (Agrawala & Van Aalst 2008). Thus, for example, initiatives aimed at health and education may enhance human capital; initiatives that focus on local institutions and organizations may improve social capital; infrastructure projects should have beneficial effects in terms of physical capital (Brooks *et al.* 2005); initiatives aimed at land investment, intensification, or conservation may enhance natural capital. Initiatives aimed at enhancing financial services should have impacts on households' financial capital; as should employment and income-generating projects or, more generally, successful development initiatives that in some fashion serve to improve local livelihoods, at least in the intermediate term. There are also obvious associations between the various types of capital: for example, financial capital may be used to improve physical or natural capital; poor health will in the long run affect other capital holdings. The following indicators were used as proxies of adaptive capacity (Table 1):

Table 1: Household assets used to develop local adaptive capacity index

Assets	Indicators	Measurement	Type of variable
	Family size	Number of people in a household	Continuous
Human	Household head's education level	Number of years attained in formal school	Continuous
	Household head's age	Number of years since born	Continuous
Social	Length lived in the area	Number of years stayed in that area	Continuous
	Savings group member		Nominal
	Other household property	Total cost for other physical assets	Continuous
Physical	Cost of house (MKW)	Total cost of building a house.	Continuous
Natural	Amount of land (Acres)	Total household land area	Continuous
	Livestock	Net livestock value	Continuous
	Access to forest resources	Ability to collect fuelwood and other non-forest timber products for household usage	Nominal
Financial	Savings income in last 12 months	Amount of money saved by the household in the previous year	Continuous

Area description

In order to respond to the research questions, a study was conducted on the western shores of Lake Malawi at a place called Nkhotakota (Figure 2). Nkhotakota is located in the central region of Malawi and is one of the five-lakeshore districts of Malawi. Nkhotakota district is a climate change hotspot and an impact area for the implementation of the National Adaptation Plan of Action (NAPA) (GoM 2006).

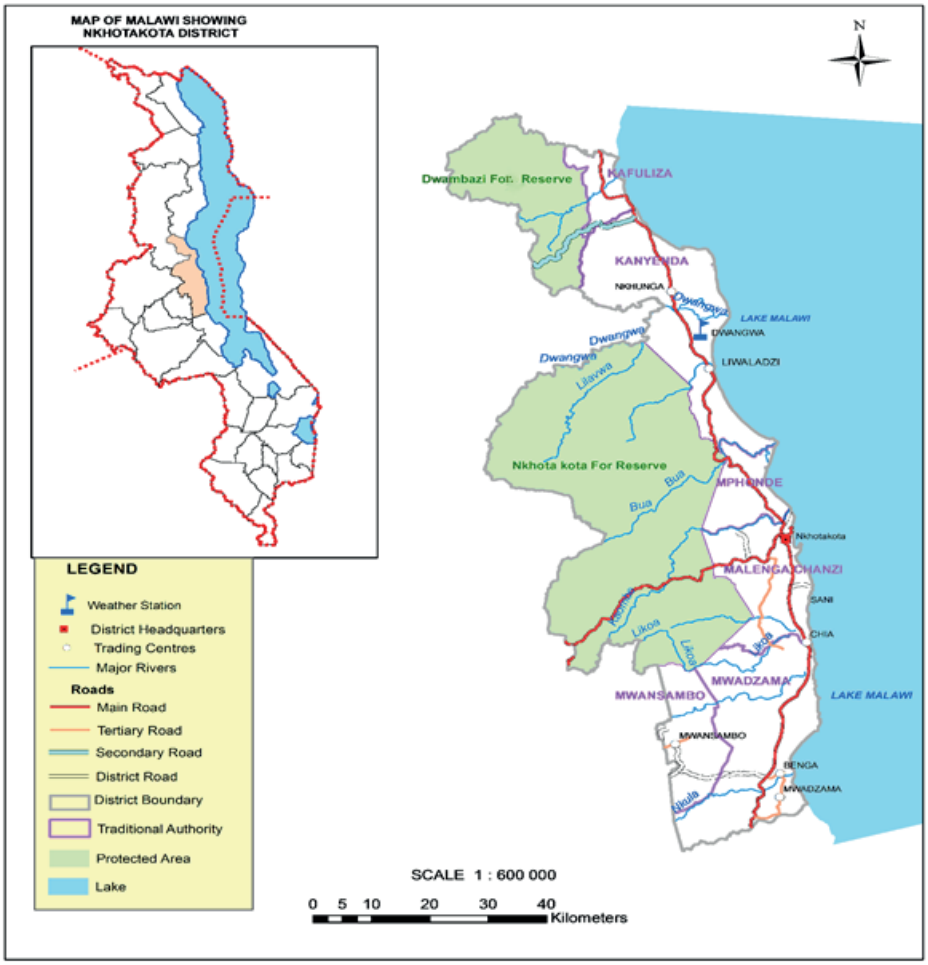

Figure 2: Map of Malawi showing Nkhotakota district and the study area. Source: (Limuwa *et al.* 2018a)

However, the climate-related changes experienced in this district could be attributed to climate variability (Limuwa *et al.* 2018a). Key extreme weather events in this district include increased incidences of dry spells, floods, droughts and strong easterly and northerly winds on the lake [ibid]. The district has a population of 393,000 with an equal ratio of women and men (GoM 2010). Women in Nkhotakota increased their role in fish post-harvest and other non-traditional roles in the fish value chain such as ownership of fishing equipment. However, such increased participation has not improved their power to control proceeds from fisheries related activities (Limuwa & Synnevåg 2018).

The majority of the inhabitats in Nkhotakota are of Chewa origin who follow a matrilineal type of kinship (GoM 2008). However, many patrilineal tribes had also been migrating to Nkhotakota in search of other livelihood sources. Nkhotakota people's major livelihoods include fishing, farming and businesses (GoM

2010; Limuwa *et al.* 2018a). Other livelihood sources like fish farming, an example of a development initiative, that could offer sustainable livelihoods seem to be challenged by lack of inputs such as quality fingerlings and feeds (Limuwa *et al.* 2018b). The people of Nkhotakota have a tradition of moving between livelihood sources, displaying flexibility in response to fish catches and agricultural production.

Development initiatives in the study area

The need to establish linkages between adaptive capacity and development initiatives is very important as it provides knowledge that is currently missing. Even though most development initiatives were not meant to address vulnerability to climate change, we hypothesize that also activities oriented towards reducing poverty, improving nutrition, and promoting sustainable livelihoods in general will have beneficial impacts on adaptive capacity (Agrawala & Van Aalst 2008).

In our analysis of development initiatives, we assumed a constant time variability in accessing the initiatives (Tumusiime and Sjaastad, 2013). In addition, we grouped the initiatives based on common themes which are directly associated to building adaptive capacity and potential to improve the general welfare of the targeted communities (Smit & Wandel 2006; Gbetibouo & Ringler 2009; Nelson *et al.* 2010a; Nelson *et al.* 2010b; Furlow *et al.* 2011; Abdul-Razak & Kruse 2017; Recha *et al.* 2017). Grouping was necessary due to the low number of beneficiaries associated with some of the individual initiative implemented in the study area. Our analysis was limited to the following groups of initiatives.

Health care

There were several health care related initiatives implemented in the study area by various players. Firstly, the Society for Women and AIDS in Malawi (SWAM) a local Non-Governmental Organization (NGO) has been building capacity of Lake Malawi women since 2005. Their initiatives included improved access to HIV preventative, care and support of women who used to rely on fishers for money. Women in fishing communities are too vulnerable and engage in transactional sex with fishers in exchange for favours that include access to fish (Haraldsdottir 2002; MacPherson *et al.* 2012; Limuwa & Synnevåg 2018). Secondly, Nkhotakota AIDS Support Organization (NASO) has been providing human immunodeficiency virus (HIV) care related services since 1992. Thirdly, the World Medical Fund, a United Kingdom (UK) based medical charity, has been providing villagers with basic medical care, which also included anti-retroviral treatment, anti-malarial treatment and infectious disease management. Fourthly, two other NGOs (Maikhanda Trust and Concern Worldwide) had each been implementing interventions geared towards reducing maternal and new-born babies' mortality.

Credit facilities

Provision of services related to accessing formal credit were scant. Only two NGOs (Vision Fund a subsidiary of World Vision International and Community Savings and Investment Promotion (COMSIP))

had been providing formal loans in the study area since 2000. These loans were aimed at building businesses while promoting the culture of saving and investments.

Infrastructure

Respondents had benefited from both government-funded and privately funded infrastructure initiatives. An example of the government-funded infrastructure was the Local Development Fund (LDF), which is a pool of all funding for local development initiatives, implemented since 2009. Its main aim is to advance implementation of the Decentralization Policy while supporting demand-driven community socio-economic infrastructure investments directly managed by the local communities. The Decent and Affordable Housing Subsidy Programme (DAHSP) that provide subsidized construction materials for the low-income households to build and improve their houses is another government-funded initiative since 2014. Furthermore, Kumudzi Kuwale, a private entity has also been providing cheap solar energy solutions in the study area since 2014.

Employment

Despite the majority of the households in the study area earning a life through fisheries and agricultural related activities, other sources of income were also realised through participating in the Public Works Programme (PWP), a safety net scheme. The initiatives target poor households by supporting labour intensive community activities. These initiatives enhance the participants' incomes, as they are paid wages for their labour.

Food production and natural resources management

The government has been promoting fisheries through initiatives like the Lake Malawi Artisanal Fisheries Development Project (LMAFDP), which started in 2003 and ended in 2008. The Project was intended to improve household incomes by enhancing the management and utilisation of fisheries resources.

Other natural resources management initiatives implemented in the area were through Total Land Care (TLC) an NGO and Lilongwe University of Agriculture and Natural Resources (LUANAR). TLC's initiative started in August 2008 and ended in July 2013. The initiative promoted adaptation to climate change in order to improve the livelihoods of rural communities. LUANAR has been implementing the Capacity Building for Managing Climate Change in Malawi (CABMACC), aimed to enhance innovative responses and capacity for adapting to climate change. In the study area, CABMACC implemented a project on fish post-harvest technologies. The project is aimed at reducing deforestation while improving fish quality through use of solar fish driers.

The National Smallholder Farmers' Association of Malawi (NASFAM), the largest smallholder union, has been promoting improved access to inputs and marketing of farm produce since 1998. A local NGO,

Foundation for Community and Capacity Development (FOCCAD), has been promoting economic independence for poor youth and women in the fishing communities of Nkhotakota through vocational training in agriculture. In addition to these initiatives, the government has been implementing the agricultural input subsidy programme since 2005 for fertilisers and seeds (hybrid and composite maize). The initiative is aimed at increasing incomes of resource-poor smallholder farmers through access to agricultural inputs at affordable prices. This group of initiatives is crucial to local communities' survival, due to their dependency on natural capital.

Data Collection

Despite this study using quantitative methods, in its initial phases it also used field observations and exploratory surveys to collect data from the study sites. These surveys were open-ended and they collected data on types of development initiatives, implementers, scope of benefits, selection criteria of beneficiaries and implementation periods. This phase also helped the study to probe the district assembly and NGO officials on how development was framed within the study area. The responses from the exploratory surveys and field observations enabled development of research tools such as checklists for focus group discussions, key informant interviews, and structured questionnaires for the household surveys.

The selection procedure for household survey respondents first involved cluster sampling of villages within a 1 km radius from Lake Malawi's shoreline. Secondly, 29 villages were randomly selected from a list of villages located within the study radius. Thirdly, 399 household heads (men and women) were randomly sampled from the selected villages. The number of households sampled per village was proportional to its population in order to give every household an equal chance to participate in the study (Levy & Lemeshow 1999). Data collected in this phase included: basic household information; assets and wealth; income and costs; expenditure and savings status; and benefits associated with development initiatives.

Furthermore, we conducted fifteen (15) focus group discussions and ten (10) key informant interviews to explore issues that came out during both the exploratory and household surveys. This phase enabled the study to look at factors that hinder benefiting from development initiatives. Those interviewed during the key informant interviews included representatives of NGOs, district assembly, farmers, fishers, natural resources management committees and village leadership. The combination of exploratory surveys, household surveys, focus group discussions and key informant interviews enhanced the study's validity and reliability.

Data Analysis

Various methods were used to analyse the quantitative data from the household survey responses. These methods included descriptive statistics (means, ranges, proportions) and inferential statistics (t-tests, cross-

tabulations, correlations). Furthermore, we used the Gini coeffient to measure households' income inequalities.

In order to develop an adaptive capacity index, several indicators adapted from the five capitals of the Sustainable Livelihood Framework (Tables 1) were used. To ensure comparability, continuous indicators were normalised into a range of 0 and 1 due to differences in units of measurement (Vincent 2004; GoM 2006; Nelson *et al.* 2010b) while nominal indicators take on values of 1 or 0 (for example, access or no access). The presence of zero values for some indicators, and the emergence of negative weights (see below), necessitated aggregation of indicators via the arithmetic rather than the geometric mean. Before the normalization process, functional relationships based on theory and previous studies were identified between each indicator and the adaptive capacity. This is to say, whether a given indicator is assumed to increase or decrease adaptive capacity. The formulae for treating these relationships were separated as shown below in equations 1 and 2, for positive and negative functional relationships respectively.

$$X_{ij} = \frac{\mathrm{X}_i - \mathrm{L}}{\mathrm{H} - \mathrm{L}} \tag{1}$$

$$X_{ij} = \frac{\mathrm{H} - \mathrm{X}_i}{\mathrm{H} - \mathrm{L}} \tag{2}$$

Where, with reference to a particular column, H and L are highest and lowest values respectively of the indicator, and X_i represents the indicator value with respect to household *i*. The indicators representing each of the five capitals were then weighted together to develop an overall adaptive capacity index. Rather than methods such as expert judgement (Brooks *et al.* 2005; Abdul-Razak & Kruse 2017) and arbitrary choice of equal weight (O'Brien *et al.* 2004), Principal Component Analysis (PCA) was used as a weighting method (Cutter *et al.* 2003; Gbetibouo & Ringler 2009; Nelson *et al.* 2010b; Banda & Phiri 2016).

PCA is a statistical method used to extract the linear combinations that best capture the common information from a large group of variables (Filmer & Pritchett 1998). PCA generates composite indices by using the eigenvalues greater than one rule of thumb (Kaiser 1974). The rule states that, "there are many reliable factors as there are eigenvalues greater than one." After retaining components with eigenvalues greater than one, factor loadings were generated for all indicators and these were used as weights (Žurovec *et al.* 2017). Furthermore, the second step PCA was run using the index values generated from aggregation of indicators of the five asset groups; these were aggregated to give a total adaptive capacity index for every household. To construct the adaptive capacity index, the following formula was used:

$$I_j = \sum_{i=1}^{k} bi \left(\frac{a_{j,i} - x_i}{s_i}\right) \tag{3}$$

Where I is the index value, j is a specific household, b is the weight from first component of the PCA for respective indicators, a is the indicator value, x_i is the mean value for the indicator and s is the standard deviation of the indicators. Categorical indicators such as membership to savings group and access to forest were re-coded into binary variables (Vyas & Kumaranayake 2006; Kolenikov & Angeles 2009) in order to conform with Principal Component Analysis. In summary, the first step PCA gives an indication of the impact of individual indicators within the capital group, whereas the second step PCA indicates the relative importance of the five capital types that define the overall adaptive capacity (Nelson *et al.* 2010a).

Results

Characteristics of the respondents

Of the 399 respondents sampled in the study, 83% were male-headed households and 17% were female-headed households. The majority (73%) of the respondents were from the Chewa tribe. Other tribes included Yao (12%), Tonga (6%), Tumbuka (4%), Lhomwe (2%), Sena (1%), and Nkhonde (1%). These respondents belonged to the two major religion sects of Islam (57%) and Christianity (42%). The majority of respondents (68%) were originally born in the study area; the remainder (32%) had migrated to the study area.

Only 110 households (28%) benefited from any of the five groups of initiatives we evaluated. Among beneficiaries, the ratio of male-headed households (85%) to female-headed households (15%) was not significantly different from that of the overall sample. Table 2 summarizes the respondents' socio-economic characteristics. Of the many socio-economic factors analysed, differences in time lived in the area, land-holding size, incomes from fisheries and remittance were statistically significant between beneficiaries and non-beneficiaries. Even though households' overall net annual incomes was not significantly different between the two groups, non-beneficiaries had higher fisheries income than beneficiaries. Non-beneficiaries also received significantly higher remittances than beneficiaries and possessed significantly larger land holdings. Beneficiaries had been residents in the study area longer than non-beneficiaries had.

Table 2: Socio – economic characteristics for the respondents

	Study sample (N=399)		Beneficiaries (N= 110)		Non-beneficiaries (N=289)	
Household socio – economic factors	**Sample mean**	**Max (min) values**	**Sample mean**	**Max (min) values**	**Sample mean**	**Max (min) values**
Female head of household (%)	16.8	-	14.5	-	17.6	-
Members of savings group (%)	21.0	-	27.3	-	18.3	-
Access to forest (%)	15.0	-	22.0	-	13.0	-
Involved in fisheries (%)	46.0	-	46.0	-	45.7	-
Education of household head (yr)	4.8	16 (0)	5.6	15 (1)	5.2	17 (1)
Age of household head (yr)	41.6	85 (19)	43.6	84 (20)	40.8	85 (19)
Household size	5.6	17 (1)	5.8	12 (1)	5.5	17 (1)
Land holding size (Acre)	3.2	102.8 (0.1)	1.4	12 (0.1)	3.9**	102.8 (0.1)
Length stayed in the area (yr)	32.8	85 (1)	36.7	84 (0)	31.2**	85 (0)
Adaptive capacity index	0	2.4 (-2.6)	-0.005	2.2 (-2.3)	0.002	2.4 (-2.56)
Income sources	2.03	4 (0)	2.0	4 (0)	2.0	4 (0)
Savings income (MKW)	74,146.23	5,000,000 (0)	58,745.87	2,000,000 (0)	79,954.67	5,000,000 (0)
Total assets (MKW)	164,317.37	7,457,500 (0)	225,359.41	7,457,500 (0)	1410,83.37	5,290,500 (0)
Annual net income (MKW)	1,123,946.72	27,116,100 (-660,502)	856,272	9,923,000 (-317,800)	1,228,590	27,116,100 (-660,502)
Capture fisheries income (MKW)	2,376,987.28	27,632,500 (-300,000)	1,798,816	9,470,000 (190,000)	2,586,403*	27,632,500 (-300,000)
Remittance income (MKW)	26,509.36	450,000(-330,000)	12,499	300,000 (-330,000)	321,13*	450,000 (-175,000)
Agriculture income (MKW)	209,640.20	12,559,200 (-192,000)	225,844	1,562,600 (-100)	203,374	12,559,200 (-192,000)
Business income (MKW)	256,201.75	1,800,000 (500)	176,547	648,000 (7,000)	296,028	1,800,000 (500)
Casual labour & formal employment income (MKW)	153,511.83	1,800,00 (4,000)	128,625	768,000 (10,000)	162,168	1,800,00 (4,000)

Notes: *, **, and *** indicate independent sample t-test at significance levels of 0.10, 0.05, and 0.01 respectively. 1US$ = MKW 725

The study further revealed differences between beneficiaries and non-beneficiaries' in the means of some basic household characteristics, grouped according to the five development initiatives (Table 3). In those cases where significant differences emerged, non-beneficiaries tended to have lower age of household head, lower education of household head, shorter time in the study area, and larger land holdings. We will return to some of differences later in the section on targeting.

Table 4 displays primary occupations and income sources. Agriculture (36%) and capture fisheries (36%) were equally important as a primary occupation, with businesses (15%), casual labour (7%) and formal employment (1%) following. Some (6%) of respondents did not have a primary occupation. Fisheries and agriculture made significant contribution to households' annual income for both beneficiaries and non-beneficiaries. Beneficiaries had a higher proportion of income from agriculture than the non-beneficiaries did, while non-beneficiaries earned more from capture fisheries than did beneficiaries. The study further showed a significant difference (*Cross tabulation = 13.99, df = 8, p<0.1*) between benefiting from any of the initiatives and the household's primary occupation.

Table 3: Socio-economic characteristics of beneficiaries and non - beneficiaries.

Variables	Healthcare (N=16)		Access to credit (N=7)		Infrastructure (N=32)		Employment (N=34)		Improved food production (N=44)		Any benefit (N=110)	
	B	NB	B	NB	B	NB	B	NB	B	NB	B	NB
Family size	5.6	5.6	5.1	5.6	6.4	5.5**	6.1	5.6	5.5	5.6	5.8	5.5
Household head's age	36.5	41.8	34.6	41.8	46.8	41.2**	44.4	41.4	46.2	41.0**	43.6	40.1
Household head' education	7.1	5.2**	7.9	5.3*	4.6	5.4	5.7	5.3	5.3	5.3	5.6	5.2
Length lived in the area	33.9	32.8	34.6	32.8	40.1	32.1**	42.0	32.0***	34.3	32.6	36.7	31.2**
Land holding size	1.0	3.3***	0.9	3.2***	2.1	3.3	1.2	3.3***	1.3	3.4**	1.4	3.9**
Income sources	2.1	2.0	2.1	2.0	2.1	2.0	1.7	2.1*	2.1	2.0	2.0	2.0
Net annual income	579,579	1,148,771	484,328	1,137,404*	701,277	1,165,504*	670,022	1,165,700*	1,308,980	1,103,260	856,272	1,228,591

Notes: *, **, and *** indicate independent sample t-test at significance levels of 0.10, 0.05, and 0.01 respectively. B and NB represent beneficiaries and non-beneficiaries respectively.

Table 4: Primary occupations and income sources of beneficiaries and non-beneficiaries

	Primary occupation			Income share		
	Whole sample	Beneficiaries	Non-beneficiaries	Whole sample	Beneficiaries	Non-beneficiaries
Agriculture	33%	36%	32%	10%	17%	11%
Capture fisheries	39%	36%	40%	75%	74%	80%
Remittances				2%	1%	1%
Business	12%	14%	10%	3%	3%	3%
Casual labour wage	12%	7%	13%	3%	3%	3%
Formal employment	1%	1%	3%			
No occupation	3.3%	6%	2%			
Hiring land & equipment				7%	2%	2%

Source: Livelihoods survey data, 2017

Adaptive capacity

In order to evaluate the impact of development initiatives in improving adaptive capacity, the study used the five capitals of the SLF to build an adaptive capacity index. Principal Component Analysis (PCA) was used to aggregate the household's capital profiles as proxy indicators for adaptive capacity index (Table 5). The selected indicators showed enough sampling adequacy. This condition was satisfied because the minimum accepted value for Kaiser-Meyer – Olkin (KMO) measure of 0.5 was attained (Kaiser 1974). Furthermore, the Bartlett's test of sphericity was also statistical significant ($p<0.001$) indicating that correlations between the selected indicators were sufficiently large to enable do a PCA. The principal components that were picked were those with eigenvalues of 1 or more.

Table 5: PCA results for indices generation for adaptive capacity status.

Capital	Indicator	Weights (First principal component)	Variation explained (%)	KMO
	Family size	0.25		
Human	Education level	0.57	43.7	0.50
	Age	-0.61		
	Years lived in the area	0.68		
Social	Savings group member	-0.68	53.9	0.50
	Cost of other household property	0.66		
Physical	Cost of house	0.66	56.8	0.50
	Land owned	0.53		
Natural	Access to forest	-0.46	34.8	0.50
	Livestock	0.68		

Notes: N = 399. *, **, and *** indicate Bartlett's Test of sphericity at significance levels of 0.10, 0.05, and 0.01, respectively. All five capitals have an extracted eigenvalue of greater than one.

Financial capital was not subjected to aggregation because there is only one proxy indicator (savings in the last 12 months). The results for the other four capitals displayed negative weights, especially for household head age, being a member of a savings group, and access to forest products. The negative weights are interpreted in absolute terms but they imply presence of negative correlation between indicators (Field 2013; Pituch & Stevens 2015). For example, age was negatively correlated with both family size and education level. The total variation explained by the indicators in the aggregation process among the capitals ranged from 34.8% to 56.8% with natural and physical capital explaining the lowest and highest respectively.

The second stage of aggregation revealed that social capital had a negative weight (Table 6). However, aggregation of the five capitals explained 65.3% of total variation in (non-weighted) adaptive capacity.

Table 6: Aggregation of capitals into an adaptive capacity index.

Capital	Weights	Variation explained (%)	KMO
	Component 1		
Human	0.04		
Social	-0.22		
Physical	0.88	65.3	0.56
Natural	0.80		
Financial	0.64		

Source: Livelihoods survey data, 2017 Bartlett's Test of sphericity Approx. Chi-Square= 329, df=10, p<0.001

Table 7 shows mean Adaptive Capacity Indices (ACI) for beneficiaries and non-beneficiaries. Significant differences were only observed between beneficiaries and non-beneficiaries for access to credit and infrastructure initiatives. Non-beneficiaries for credit initiatives had a higher ACI compared to the beneficiaries. On the other hand, beneficiaries for infrastructure had a higher ACI compared to non-beneficiaries. Overall, the ACI was slightly higher for non-beneficiaries, but the difference was not significant.

Table 7: Mean adaptive capacity for beneficiaries and non-beneficiaries

Initiative	Beneficiaries	Non- beneficiaries
Healthcare	-0.32	0.013
Access to credit	-0.86	0.015**
Infrastructure	0.30	-0.03*
Employment	0.15	-0.013
Improved food production	0.026	-0.003
Any benefit	-0.005	0.002

Notes: *, **, and *** indicate independent sample t-test at significance levels of 0.10, 0.05, and 0.01 respectively

Income and distribution

Given the emphasis on different forms of capital in our adaptive capacity index, a question arises with respect to how this index relates to net income and its distribution. Adaptive capacity and net annual income were positively correlated ($r = 0.25, p<0.001$). From Table 8, we also see that adaptive capacity is strictly increasing with rising income quintiles.

Table 8: Adaptive capacity and net annual income quintiles

	Bottom (20%)	Bottom –Middle (20%)	Middle (20%)	Middle -Top (20%)	Top (20%)
Adaptive capacity index	-1.34	-0.58	-0.10	0.57	1.47
Net annual income (MKW)	-92,273	33,165	205,654	769,235	4,702,448

Source: Livelihoods survey data, 201

Table 9 displays the Gini coefficient with respect to the adaptive capacity index for beneficiaries and non-beneficiaries; for "any benefits" and for the different groups of benefits. Two results stand out. First, the

Gini coefficients for adaptive capacity are consistently high. Only one coefficient is below 0.61. Since our adaptive capacity index is constructed from a range of indicators of different forms of capital, this suggests that capital – writ large – is distributed very unevenly in the study area. Second, Gini coefficients are consistently lower for beneficiaries than for non-beneficiaries, suggesting that the development initiatives scrutinized may have had an equalizing effect on adaptive capacity among the beneficiaries.

Table 9: Gini coeffients and adaptive capacity indices among beneficiaries and non-beneficiaries for the five groups of initiatives.

	Beneficiaries				Non-beneficiaries			
Initiatives	**Population share**	**Income share**	**Gini**	**ACI**	**Population share**	**Income share**	**Gini**	**ACI**
Any benefits	0.28	0.21	0.66	-0.005	0.72	0.79	0.73	0.002
Access to health	0.038	0.02	0.61	-0.32	0.961	0.98	0.72	0.013
Access to credit	0.017	0.01	0.44	-0.86	0.982	0.99	0.72	0.015
Infrastructure	0.088	0.06	0.64	0.30	0.913	0.94	0.72	-0.03
Employment	0.081	0.05	0.68	0.15	0.918	0.95	0.72	-0.013
Improved food & NRM	0.11	0.12	0.65	0.026	0.89	0.88	0.72	-0.003

Gini and ACI represents Gini-coefficient and Adaptive Capacity Index respectively

Furthermore, the study also analysed income distribution and adaptive capacity based on the number of benefits per household from the five groups of initiatives (Table 10). While inequality of adaptive capacity is strictly increasing with the number of benefits (initiatives) enjoyed, adaptive capacity tends to decrease with this number (although not monotonically).

Table 10: Gini coeffients and adaptive capacity indices according to number of benefits from the five groups of initiatives.

Number of benefits	Population share	Income share	Gini	ACI
0	0.72	0.79	0.73	0.002
1	0.23	0.17	0.65	-0.89
2	0.04	0.03	0.68	-0.68
3	0.008	0.008	0.59	-0.71

Taken together, these results suggest that development initiatives may have an equalizing effect on adaptive capacity, but also that adaptive capacity among beneficiaries has yet to reach the level found among non-beneficiaries. These results also have implications for targeting issues related to these initiatives.

Targeting

When using cross-sectional data to examine impacts of development initiatives, a problem of selection bias invariably applies. Development initiatives will frequently target a specific group – health-related initiatives, for example, will tend to target those in need of health care. More generally, development initiatives will

tend to target groups perceived as in need of assistance in some dimension, depending on the nature of the initiative. On the other hand, some initiatives supply benefits that are prone to be captured by local elites – because they are favoured by distributors, in positions to influence the distribution process, or directly involved. If an association between wealth and participation in a given initiative is established, is it because the wealth was created by participation or because wealthy households were selected as beneficiaries?

Analysis of cross-sectional data proceeds, by necessity, from an assumption that selection bias is non-existent or trivial. In the strictest sense, this implies a non-biased (e.g. random) selection of beneficiaries, and hence distribution of benefits. For studies such as ours, where a number of different initiatives are considered, selection criteria may differ widely from initiative to another. Given plausible exogenous instruments at the household level, capable of explaining a sufficient degree of variation in explanatory variables, a two-stage least square procedure could overcome the problem. Such instruments were not available in our data.

The trend line in Figure 3 shows that adaptive capacity increased as the number of years as a beneficiary increased. A Pearson correlation test revealed, however, that the relationship is not statistically significant ($r=0.03$, $p>0.05$) so this is at best a weak indication that causation predominantly runs from benefit to adaptive capacity rather than the opposite.

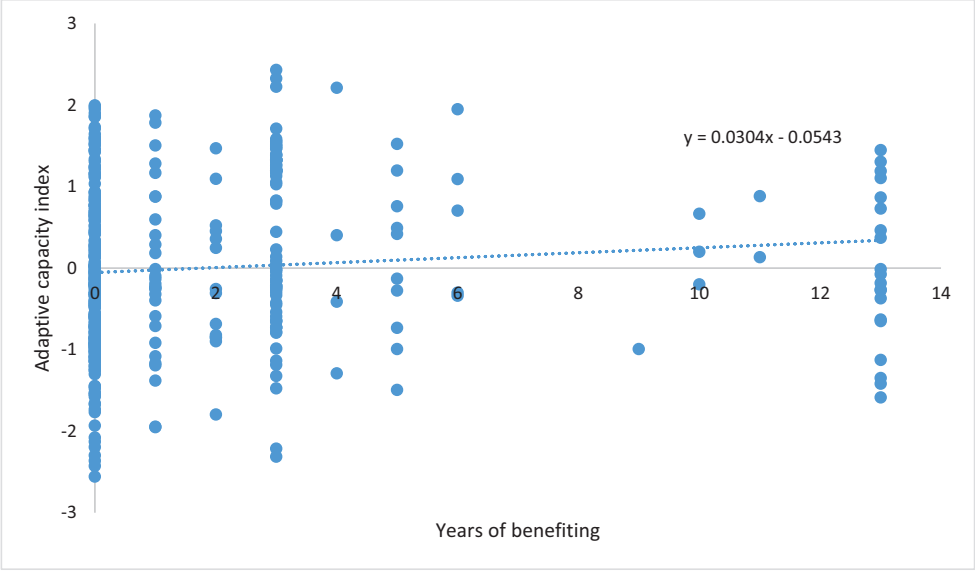

Figure 3: Relationship between adaptive capacity and years of benefiting from different initiatives

Results above have revealed, in particular, that households with high fisheries income and tended to be among the non-beneficiaries, pointing to selection bias in favour of agricultural dependence. Selection,

however, also favoured households with low remittances, thus presumably without significant income from extended family in other locations. Moreover, adaptive capacity was more evenly distributed among beneficiaries than non-beneficiaries but also generally still lower among the former group than the latter. Overall, the picture that emerges is one where development initiatives in the study area, writ large, appear successfully to target groups in genuine need rather than become sources of local elite capture. They thus will tend to have both beneficial and equalizing effect on adaptive capacity, construed as an amalgamation of the five capitals of the SLF framework.

Discussion and Conclusion

This study examined the impact of development initiatives along Lake Malawi on households' adaptive capacity. Most of these initiatives were not designed with adaptive capacity in mind, but given a conceptualization of adaptive capacity as an aggregation of the five capitals of the sustainable livelihoods framework, we would still expect such initiatives to have an impact, especially in the intermediate to long term.

Overall, adapative capacity was slightly higher among non-beneficiaries, but not significantly different from that of beneficiaries. Compared to non-beneficiaries, adaptive capacity was significantly lower among beneficiaries of credit access while significantly higher among infrastructure beneficiaries. Good infrastructure is associated with improved adaptive capacity because in times of extreme weather events, access to markets, networks, and humanitarian aid may be critical (Adger *et al.* 2005). Access to credit should improves adaptive capacity because credit can be used as a safety net (Devereux 2001; Devereux & Sabates-Wheeler 2004; Ellis & Maliro 2013). Against this, use of credit is also associated with long-term risk, and use of informal sources (Van Bastelaer 2002) is not captured by out data.

The study further reveals a positive correlation between adaptive capacity and net income, and adaptive capacity was strictly increasing with income quintiles. This result is consistent with others on the impact of income in reducing vulnerability as it offers a safety net during hardship (Bryan *et al.* 2009; Bryan *et al.* 2013; Ellis & Maliro 2013; Musinguzi *et al.* 2015). Inequality associated with adaptive capacity was high, irrespective of benefits. However, the inequalities decreased as the number of benefits increased. Results also revealed that adaptive capacity was lower but more equally distributed among beneficiaries than among non-beneficiaries.

An obvious conclusion of this study is that a further emphasis on infrastructure initiatives may serve to enhance adaptive capacity in the study area. The results also suggest to us, however, that development initiatives in general may have beneficial effects on adaptive capacity but that these effects may be disguised by what we might term "benign" selection bias – that is, a selection of beneficiaries that favours those with low capital endowments. Building capital is often a long-term process, as is the translation of capital into

income. Our data demonstrate a close association between adaptive-capacity-as-capital and net household income. However, future research could explore how other factors such as institutions can aid adaptive capacity in the study area within different social economic groups.

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