Disentangling the determinants of food and nutrition security from tropical small-scale fisheries: tackling hidden hunger using forgotten food

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This thesis is submitted for the Degree of

Doctor of Philosophy in Environmental Science,

Lancaster Environment Centre,

Faculty of Science and Technology,

Lancaster University, Lancashire, United Kingdom

August 2024

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Abstract

Fish are rich in the micronutrients required to alleviate nutrient deficiencies but remain untapped in nutrition security discourses due to the paucity of supporting empirical data and evidence. In this thesis, I aimed to untangle factors influencing the consumption of fish to help alleviate food insecurity and nutritional deficiencies. Firstly, I sought to establish how much fish is available in Kenya, and what contribution this can make to ensure food and nutrition security at the national level. Secondly, I examined the role of subnational fish markets in facilitating the availability and accessibility of nutritious fish within coastal populations. Thirdly, I investigated how social processes and power dynamics influence people's access to fish, and their agency to acquire enough nutritious and culturally appropriate seafood among coastal communities. Finally, I assessed how household fish consumption and socio-demographics influence the contributions fish make to human health and identified successful coping mechanisms. I utilized interdisciplinary mixed approaches and drew from four theoretical frameworks (Sustainable Food System Framework, a Theory of Access, the Capability Approach, and Theory of Change) to reveal factors that influence whether fish can be used for food and nutrition security. The findings reveal that the fish supply in Kenya is species-diverse, varies nutritionally, and has the potential to help support food and nutrition security among vulnerable or targeted populations. I unravel how the context of the studied populations influences the availability, access, agency, and utilization of fish, to affect food and nutrition security. I identify policy levers for improved management and governance, that include bringing together the usually disparate food systems sectors spanning food science, public health, fisheries science, policy, and governance. This study provides empirical evidence to support a transformation in Kenya's fish food system. Further research to address identified limitations is proposed.

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Acknowledgement

Whilst a journey of a thousand miles begins with a single step, it takes the push and pull from others, just like iron sharpens iron, to see one come to the thousandth mile. But for this to happen, it took the hand of God and just as Prophet Samuel affirmed, God has been my Ebenezer - my God in whom I live, and move and have my being, all glory and honor are due to Him. Thank you, God, for being with me throughout those miles. I wish to acknowledge all the under-listed for their respective contributions to the whole process of my PhD journey.

To begin with, I am sincerely thankful to my supervisors: Prof. Christina Chemtai Hicks and Prof. Nicholas Antony James Graham for their unwavering intellectual and technical support that made my research work possible and their all-round guidance throughout this journey. I thank them for their committed time, openness, patience, mentorship, inspiration and encouragement, and their enthusiasm in the realization of sustainable fisheries for food and nutrition security. I am grateful to the PhD appraisal committee at Lancaster Environment Centre for tracking my progress and offering technical advice, especially Dr. Manoj Roy and Dr. Stuart Sharp. I greatly appreciate my internal examiner, Prof. Ian Dodd (Lancaster Environment Centre), and external examiner Prof. Fiona Nunan (Birmingham University, International Development Department) for the useful discussions and recommendations that led to the improvement of this thesis.

Secondly, I am very grateful to the Kenya Marine and Fisheries Research Institute (KMFRI) management for offering me the study leave that enabled me to focus on this PhD research work. Specifically, I thank Prof. James Njiru, the Chief Executive Officer, KMFRI; Dr. Irene Githaiga, the Director, Human Resource and Administration and the KMFRI training committee in this endeavor. Professor Julius Otieno Manyallah (formerly of University of Eldoret but presently at Jaramogi Oginga Odinga University of Science and Technology) and Dr. Timothy Rice McClanahan (Wildlife Conservation Society, Kenya Marine Programs Office, Mombasa) are well appreciated for their encouragement and recommending me for this PhD pursuit.

Thirdly, I would like to thank the following individuals for their technical help in different capacities during different stages and activities in my PhD research process: Dr. James Robinson, Dr. Eva Maire, Dr. Antonio Allegretti, Dr. Sarah Martin, Dr. Steve Wright and Mark Hamilton (for their specific help, support and friendship throughout my PhD whilst at Lancaster University); Dr. Andrew L. Thorne-Lyman (Johns Hopkins Bloomberg School of Public Health, Baltimore, USA) for technical help with developing household survey questionnaire, Ms. Peris Macharia for research assistantship during social surveys in Mijikenda-Malindi, Shimoni and Kibuyuni, Ms. Clarah Kingi, Ms. Margaret Mkutano, Ms. Nelly Ndomasi and Mr. Francis Baya for assisting with the market surveys in Mtwapa, Malindi and Ukunda; Mr. Benrick Ogutu and Mr. Stephen Ndegwa (the Kenya Fisheries Service for assisting with Statistical Bulletin data), Mr. Maxwel Azali (my former student turned my R advisor when stuck with some Error messages!), Mr. Nimrod Ishmael (for assistance with production of maps) and co-worker and reliable field research assistant Ms. Faith Kemunto Kimanga for assisting with the household surveys in Watamu, Mkwiro and Vanga villages. It was indeed a great pleasure working with you, all valuable people and I will always remember our time working together whether in the communities out there in the villages, the market, in the office, or virtually. You made my journey to progress towards the mark timely.

Finally, I would like to heartily thank all the coastal communities' participants and village guides in the six villages and three fish market centres where I carried out this work and all those who supported me and made the time during my PhD fieldwork in Kenya worthwhile. I close by dedicating this thesis work to my beloved family, specifically my wife Rose Metah Shitemi for love felt from afar during the many times I was away; My daughters Anne Omuronji Omukoto, Esther Nechesa Omukoto and Naomi Adhiambo-Lusiche Omukoto for the time dearly missed from their loving daddy. God's providence kept me going through it all, all glory and honor to Him.

Declaration of the contribution of others

Research funding

This PhD was made possible through funding from the European Research Council through the project Hidden Hunger Forgotten Food, FAIRFISH (Grant agreement ID: 759457), a ERC-STG - Starting Grant awarded to Prof. Christina Chemtai Hicks of Lancaster Environment Centre, Lancaster University.

Research support

Field support

Peris Macharia, Clarah Kingi, Margaret Mkutano, Nelly Ndomasi, Francis Baya, Faith K. Kimanga

Secondary data provision

Benrick Ogutu, Stephen Ndegwa

Market survey interviews design

Prof. Christina Chemtai Hicks

Social surveys guide questions design

Prof. Christina Chemtai Hicks

Household surveys questionnaire design

Prof. Christina Chemtai Hicks, Dr. Andrew L. Thorne-Lyman

Data analysis, maps, and visualization support

Prof. Christina Chemtai Hicks, Prof. Nick AJ Graham, Dr. James Robinson, Dr. Eva Maire, Dr. Sarah Martin, Dr. Steve Wright, Mark Hamilton, Maxwel Azali, Nimrod Ishmael

Editorial support

Prof. Christina Chemtai Hicks, Prof. Nick AJ Graham, Dr. Antonio Allegretti, Dr. Andrew L. Thorne-Lyman

Research permit and ethics

All fieldwork research presented in this thesis was conducted after receiving approval from the Faculty of Science and Technology Research Ethics Committee (FSTREC) of Lancaster University, United Kingdom (FSTREC Reference: FST18132) and research clearance from the Kenya's National Commission for Science, Technology, and Innovation (NACOSTI), License No: NACOSTI/P/21/10978. For all the interviews done, verbal consent was sought from the participants before they were interviewed.

Author contributions by research chapters

Supervisors

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Other co-authors

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Chapter 2 – Fish contributions toward nutritional security in Kenya.

JOO: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. NAJG: Supervision, Methodology, Visualization, Writing – review & editing. CCH: Conceptualization, Supervision, Project administration, Funding acquisition, Methodology, Writing – review & editing.

Chapter 3 – Fish markets facilitate nutrition security in coastal Kenya: empirical evidence for policy leveraging.

JOO: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. NAJG: Supervision, Methodology, Visualization, Writing – review & editing. CCH: Conceptualization, Supervision, Project administration, Funding acquisition, Methodology, Writing – review & editing.

Chapter 4 – Social processes and power dynamics drive food and nutrition security in coastal communities interacting with tropical small-scale fisheries.

JOO: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. AA: Visualization, Writing – review & editing. CCH: Conceptualization, Supervision, Project administration, Funding acquisition, Methodology, Writing – review & editing.

Chapter 5 – Fish consumption and household sociodemographic factors impact human health outcomes: evidence from coastal fishery-adjacent communities in Kenya.

JOO: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. NAJG: Supervision, Methodology, Visualization, Writing – review & editing. ALT: Methodology, Writing – review & editing. CCH: Conceptualization, Supervision, Project administration, Funding acquisition, Methodology, Writing – review & editing.

Candidate’s declaration of thesis originality

I hereby declare that this PhD thesis is my original work and has not been submitted in substantially the same form for examination and the award of a higher degree elsewhere. Where references to work done by others were made, these have been duly acknowledged, cited, and referenced.

I declare that the word length of this thesis is 45,545 words, and therefore conforms to the permitted maximum of 80,000 words excluding front preliminary pages, appendices, and list of references.

Signature:

Johnstone Omukoto Omuhaya
Lancaster Environment Centre
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August 2024

Memorable quotes

1. “Everyone has the right to adequate food in a quantity and quality sufficient to satisfy their dietary needs. One of the key challenges going forward is to ***shine a light on food quality, to address hidden hunger”*** (Klaus *et al.*, 2014).
2. “The right nutrition at the right time builds the capacity to dream, it fuels the power to achieve, and it lays the foundation upon which to build a better world” (nutritionintl.org).

Contributions during the PhD

Peer-reviewed publications - Thesis

Omukoto JO, Graham NAJ, Hicks CC. (2024). Fish markets facilitate nutrition security in coastal Kenya: empirical evidence for policy leveraging. Marine Policy 164 (2024) 106179

Omukoto, J.O., Graham, N.A. & Hicks, C.C. (2024) Fish contributions toward nutritional security in Kenya. Food Security. https://doi.org/10.1007/s12571-024-01459-8

In preparation for submitting to peer-review - Thesis

Omukoto JO, Graham NAJ, Allegretti A, Hicks CC. Social processes and power dynamics drive food and nutrition security in coastal communities interacting with tropical small-scale fisheries (in preparation for submission to World Development Journal)

Omukoto JO, Graham NAJ, Thorne-Lyman AL, Hicks CC. Fish consumption and household sociodemographic factors impact human health outcomes: evidence from coastal fishery-adjacent communities in Kenya (in preparation for submission to Frontiers in Sustainable Food Systems Journal)

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James PW Robinson, David J Mills, Godfred Ameyaw Asiedu, Kendra Byrd, Maria del Mar Mancha Cisneros, Philippa J Cohen, Kathryn J Fiorella, Nicholas AJ Graham, M Aaron MacNeil, Eva Maire, Emmanuel K Mbaru, Gianluigi Nico, Johnstone O Omukoto, Fiona Simmance, Christina C Hicks. 2022. Small pelagic fish supply abundant and affordable micronutrients to low- and middle-income countries. Nature Food. https://doi.org/10.1038/s43016-022-00643-3

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Chapter 1. General introduction

Fish contain vital nutrients essential for human health, but the analysis of the nutrient content of fish supplies and their potential to address nutrient deficiencies is still anecdotal in many countries. In fact, seafood generally remains less researched compared to terrestrial animal and plant production in food security discourses (Stetkiewicz *et al.*, 2022). Malnutrition due to nutrient deficiencies, excesses, or imbalances continues to manifest as a global health challenge (FAO, IFAD, UNICEF, WFP and WHO, 2023) resulting in health inequalities in many countries (Borras and Mohamed, 2020). By the year 2022, an estimated 9.2% (736 million people) of the world population, especially in tropical developing countries, still suffered from micronutrient deficiencies (termed as "hidden hunger") due to a lack of essential micronutrients such as vitamins, zinc, iodine, iron and calcium (FAO, IFAD, UNICEF, WFP and WHO, 2022; Cartmill *et al.*, 2022; FAO, IFAD, UNICEF, WFP and WHO, 2023). Projections suggest that nearly 600 million people will be chronically undernourished in 2030 (FAO, IFAD, UNICEF, WFP and WHO, 2023). Attaining full benefits from fish for food and nutrition security demands their inclusion in the general food policy agenda. Unfortunately, small-scale fisheries, which provide at least 40% of the global catch from capture fisheries (FAO *et al.*, 2023) have yet to receive concerted attention in many countries. For example, in Kenya, up until recently fish has been a "forgotten food" in policy and governance discourses on food systems, yet it is vital to supporting the food and nutrition needs of many people. Indeed small-scale fisheries support the livelihoods of over 490 million people, predominantly in low-income countries (FAO *et al.*, 2023). In this chapter, I put into context the role of fish and small-scale fisheries for food and nutrition security and lay the background information for the PhD study. I then present the research theoretical frameworks and methodological approach, thesis aims, research questions, study objectives, the contribution this thesis makes to filling the gaps in existing knowledge and present an outline of the thesis.

1.1 Global to local contextualization of food and nutrition security and the role of small-scale fisheries

Unfulfilled food requirements, nutritional excesses, imbalances, or deficiencies, and the resultant incidences of malnutrition among global human populations continue indiscriminately among developed and developing nations. This poses a great challenge to the attainment of sustainable development goal number 2 (SDG 2) – attaining zero hunger and SDG 3 – ensuring good health and well-being by the year 2030. Food security is considered achieved when all people, at all times have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences and is supported by an environment of adequate sanitation, water provision, and health care services, enabling a healthy and active life (FAO, 1996; Committee on World Food Security, 2012). Food security and nutrition security are closely linked but not the same (Ingram, 2020). While there isn't a formal definition of nutrition security, it emphasizes the importance of food quality (food security only mentions nutritious food) and includes outcomes (e.g. when food security 'promotes well-being and prevents and if needed, treats disease') (Mozaffarian *et al.*, 2021). Nutrition security recognizes that sufficient food or even nutrients alone does not guarantee nutrition security. Therefore, in this thesis, I use food and nutrition security to refer to both food security as defined above and extend to include nutrition security to capture the health outcomes of food security.

Realizing food and nutrition security remains a basic need that is commonly voiced at global, regional, national, community, and individual scales (Smith *et al.*, 2000; Carletto *et al.*, 2013; FAO, IFAD, UNICEF, WFP and WHO, 2021; Banik, 2019; Bethancourt *et al.*, 2023; Garcia *et al.*, 2020). However, many challenges to meeting food and nutrition security continue to feature as critical global concerns (HLPE, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2022). One key aspect of food and nutrition security is malnutrition, defined as deficiencies or excesses in nutrient intake, imbalance of essential nutrients, or impaired nutrient utilization (WHO, 2021). Malnutrition may manifest itself in the form of undernutrition, micronutrient deficiencies, or overweight and obesity (Shrestha *et al.*, 2022; Korir *et al.*, 2023; Hossain, 2017). Global and in-country malnutrition rates have been reported to exceed poverty rates with an estimated 9% of the global human population being poor but an estimated 25% experiencing micronutrient deficiencies in their diets (Mahrt *et al.*, 2022; HLPE, 2020).

The nutritional challenge faced by the global human population compelled the United Nations to declare 2016-2025 as a decade of action on nutrition (World Health Organization, 2018) with the Food and Agriculture Organization (FAO) prioritizing better nutrition in the strategic framework 2022-2031(FAO, 2022a). Despite the efforts to address hunger and malnutrition, more than one-third (278 million) of the people who were affected by hunger in 2021 in the world were in Africa (FAO, IFAD, UNICEF, WFP and WHO, 2022). Furthermore, although most of the world's undernourished people live in Asia, Africa is the region where the prevalence is highest (FAO, IFAD, UNICEF, WFP and WHO, 2022). Noting that malnutrition remains prevalent in most African countries, the African Union (AU) developed the Africa Regional Nutrition Strategy 2015-2025 (ARNS 2015-2025) to address the malnutrition challenge. Following in the same steps, national efforts to address malnutrition in Kenya were domesticated by the country committing to the Sustainable Development Goals (SDGs), the Scaling Up Nutrition (SUN) movement, the World Health Assembly (WHA) 2025 nutrition targets, the United Nations (UN) Decade of Action on Nutrition (2016–2025), and the second International Conference on Nutrition (ICN2) Declaration and Plan of Action (Government of Kenya, Ministry of Health, 2018). These agreements lay down the foundation for addressing the immediate, underlying and basic causes of malnutrition including expanding the political, economic, social, and technological space for nutrition actions (Nutrition International, 2021; Government of Kenya, Ministry of Health, 2018). Therefore, the need to tackle malnutrition as a basic human need to ensure healthy diets for all and nutrition attainment by the most vulnerable beckons necessary interventions at all scales.

The milestones to addressing food and nutrition challenges among nations have faced various roadblocks, with each country experiencing varying intensities and types of issues to redress. The reasons for this variability include disparities in levels of development, different policies prioritized, political agendas, socioeconomics, culture, the North-South global investment divide, shifting consumer behavior, climate variability and extremes, economic slowdowns and downturns, the coronavirus disease of 2019 (COVID-19) pandemic, and most recently the ongoing war in Ukraine (FAO, IFAD, UNICEF, WFP and WHO, 2023). The latter two have halted recent progress towards SDG 2 (FAO, 2021; FAO, IFAD, UNICEF, WFP and WHO, 2020; Garcia *et al.*, 2020; Gebeyehu *et al.*, 2022; Lusseau and Mancini, 2019; Ruel and Alderman, 2013; Vågsholm *et al.*, 2020). The COVID-19 pandemic resulted in between 691 and 783 million people in the world being faced with hunger in 2022, an increase of approximately 122 million from 2019 (FAO, IFAD, UNICEF, WFP and WHO, 2023), and the ongoing war in Ukraine is expected to compromise the realization of the Sustainable Development Goals (SDGs) (Ben Hassen and El Bilali, 2022; FAO, IFAD, UNICEF, WFP and WHO, 2023).

Fish are mostly under-recognized and often neglected in policies on food systems. Yet tropical small-scale fisheries deliver diverse beneficial ecological, economic, food, nutritional, social, cultural, and moral outcomes (Thilsted *et al.*, 2016; Bogard *et al.*, 2017; FAO, IFAD, UNICEF, WFP and WHO, 2020; HLPE, 2020; Kleisner *et al.*, 2021; Maire *et al.*, 2021; Stacey *et al.*, 2021; Arthur *et al.*, 2021; FAO, IFAD, UNICEF, WFP and WHO, 2022; FAO *et al.*, 2023). Both fisheries (marine and freshwater) and aquaculture systems are increasingly recognized for their contributions to food and nutritional security (FAO, IFAD, UNICEF, WFP and WHO, 2020; Gephart *et al.*, 2021; Obiero *et al.*, 2019; O'Meara *et al.*, 2021; Thilsted *et al.*, 2016; Willett *et al.*, 2019). Fish provide essential nutrition to over 4 billion people and contribute more than one-sixth of animal protein to the diets of the global population (Béné *et al.*, 2015; FAO, 2018, 2022b; Kawarazuka and Béné, 2011). Furthermore, fish are rich in a diversity of nutrients that are vital for human health outcomes (FAO, IFAD, UNICEF, WFP and WHO, 2020; Hicks *et al.*, 2019; Maire *et al.*, 2021; Robinson *et al.*, 2022a; Taylor *et al.*, 2019), including micronutrients (vitamins and minerals) which are essential for health, development, and growth of humans (Mohanty *et al.*, 2016). Notably, fish and fisheries are particularly important in rural areas of the tropics (FAO *et al.*, 2023), that are characterized by a lower dietary diversity and higher rates of food insecurity (Thompson and Amoroso, 2014). Despite the foregoing, poor diets and malnutrition continue to pose the greatest global social challenges (2022 Global Nutrition Report, 2022). It has been estimated that between 690 - 783 million people were affected by hunger in 2022 and almost 3.1 billion people were reported to be unable to afford a healthy diet (FAO, IFAD, UNICEF, WFP and WHO, 2023), many of whom are in low- to middle- income nations with extensive marine coastlines and large inland water bodies. This is particularly troubling because relatively small amounts of fish are needed to alleviate some of the most prevalent and damaging nutritional deficiencies (Hicks *et al.*, 2019; Golden *et al.*, 2021; FAO, 2018). For example, the average recommended nutrient intakes (RNI) of calcium, iron, selenium, zinc, and vitamin A for a child under five years old are 520 mg/day, 4.8 mg/day,16.4 μg/day, 4.4 mg/day and 426.7 μgRE/day respectively (FAO/WHO, 2004; Institute of Medicine, 2006). To attain 33% of RNI across these five micronutrients and omega-3 fatty acids, the child would need to consume between 46-125 g of fish (Chapter 2 of this thesis) depending upon the species of fish consumed.

Kenya's food security situation remains challenging with over 72% of the total population experiencing moderate or severe food insecurity and 28% experiencing severe food insecurity during 2020-2022 (FAO, IFAD, UNICEF, WFP and WHO, 2023). The 2021 Global Hunger Index (GHI) ranked Kenya 87th out of the 116 countries with sufficient data to calculate 2021 GHI scores, and with a score of 23.2, Kenya has a level of hunger that is considered serious (Concern Worldwide/Welthungerhilfe, 2021). According to the national guidelines for healthy diets and physical activity report (Ministry of Health, 2017), the people of Kenya still experience the triple burden of malnutrition with 26% of children under the age of five years being stunted, 4% wasted, and 11% underweight. Among the adult population, 9% of women aged 15-49 years are reported as underweight. Micronutrient deficiencies are highly prevalent among women and children under the age of five years. The percent undernourishment prevalence has gone up slightly from 25.6% during 2018-2020 to 26.9% in 2019-2021. The third burden of overnutrition is reflected in an increasing prevalence of people who are overweight or obese in the country (Mkuu *et al.*, 2021). Micronutrient deficiencies remain a public health concern, with inadequate intakes of calcium, iron, zinc, vitamin A, and animal-sourced protein reported for children under five years (Byrd et al., 2018; Codjia et al., 2024; Kamau-Mbuthia et al., 2023; Ryckman et al., 2022; Stewart et al., 2019) resulting in nearly one-third of children aged 6-59 months being anemic, 9.2% with Vitamin A Deficiencies (VAD) and the prevalence of zinc deficiency at 83.3% (Kenya Ministry of Health, 2011).

Although there are several sectoral policy documents addressing food security and nutrition in Kenya, three policy documents are key (the National Food and Nutrition Security Policy (FNSP) of 2011, the National Food and Nutrition Security Policy Implementation Framework of 2017-2022, and the Agricultural Policy of 2021). However, the importance of fish in the diets of Kenyans has not been comprehensively incorporated into food security policy and strategies despite fish being indicated among the nutrient-rich foods. For example, the latest Agricultural Policy of 2021 recognizes food security as a fundamental right but only highlights the challenges, opportunities, and interventions for sustainable development of crops, livestock, and fisheries sub-sectors; the Kenya Health Policy of 2021-2030 only recognizes nutrition among other determinants of health; while the National Oceans and Fisheries Policy of 2008 mentions the role of fish to food security and nutritional benefit and indicates the need to enhance food supply and food security.

A better understanding of how fish can be incorporated into current food systems to address food and nutrition security is necessary to enable informed mainstreaming of small-scale fisheries, an often "forgotten food", in food policy programs and planning at local, national, regional, and global scales (Chuenpagdee and Jentoft, 2018; Bennett *et al.*, 2021b; Rivero *et al.*, 2022; FAO, 2022b). Empirical studies of the contribution of small-scale fisheries to food and nutrition security are still in their infancy in the Western Indian Ocean region, more so in Kenya. Kenya is one of the tropical countries where fish consumption by indigenous communities close to small-scale fisheries has been noted to be particularly high (McClanahan *et al.*, 2015; Hicks *et al.*, 2021). However, there is an unclear understanding of how small-scale fisheries have the potential to support human health outcomes. Thus, situating my PhD study within this United Nations decade of action on nutrition makes a plausible contribution to filling the data and knowledge gaps on the contribution of small-scale fisheries to sustainable food and nutrition security in Kenya. Additionally, overcoming hidden hunger using forgotten food in tropical contexts remains under-researched and has its inimitable challenges that need unveiling for novel solutions and interventions to be found. Therefore, through this PhD research, I applied an interdisciplinary approach to examine how fish in general and tropical small-scale fisheries, in particular, have the potential for national, subnational, and household-level food and nutrition security improvement across the six pillars (availability, access, agency, utilization, stability, and sustainability) of food and nutrition security (Clapp *et al.*, 2021; HLPE, 2020).

1.2 Unwrapping food and nutrition security

Food security has over time been defined using four pillars: availability, access, utilization, and stability (FAO, IFAD, UNICEF, WFP and WHO, 2020; HLPE, 2020). However, recently, and in response to calls from civil society, the High-Level Panel of Experts on Food Security and Nutrition (HLPE-FSN) highlighted the importance of agency and sustainability as distinct pillars. Therefore the latter two are now starting to be considered (Clapp *et al.*, 2021; FAO, IFAD, UNICEF, WFP and WHO, 2021, 2023; Manlosa, 2022), making six pillars of food security. These pillars need to be reinforced in conceptual and legal understandings of the right to food as a basic human need (HLPE, 2020). The six pillars are well defined (HLPE, 2020), have been further elaborated by Clapp and others (Clapp *et al.*, 2021), and are briefly described below. I adopted these six pillars to unravel the factors that influence how fish and tropical small-scale fisheries contribute to food security in Kenya. This was found crucial since food and agricultural policy support has rarely been explicitly designed to meet the objectives related to all pillars of food security (FAO, IFAD, UNICEF, WFP and WHO, 2022). Also, most of the policy support measures have been designed and implemented in isolation, for specific purposes, without considering the unintended consequences that they might arise in other pillars (FAO, IFAD, UNICEF, WFP and WHO, 2022). Nutrition security has become increasingly relevant in recent years, as obesity rates grow, and undernourishment persists. Although a formally accepted definition of nutrition security does not exist, nutrition security emphasizes the importance of food quality, and directs attention to health outcomes, recognizing that consuming sufficient food and nutrients is not always enough for nutrition security. Food security is thus closely related to nutrition security. In recognizing the importance of nutrition to food security, I refer to food and nutrition security together throughout this thesis.

1.2.1 Availability

Availability is the first pillar of food and nutrition security (HLPE, 2017, 2020; Clapp *et al.*, 2021). Availability implies the presence in terms of quantity and quality of food that is sufficient to satisfy the dietary needs of individuals, which is free from adverse substances, and acceptable within a given culture, supplied through domestic production or imports (Golden *et al.*, 2021; Adesina, 2022). Food availability indicates that there is the physical presence of enough stock preferred for local consumption and sourced from available production channels (Hasselberg *et al.*, 2020) at local, national, or international sources. At the household level, enough food may be available through personal production or at local markets to feed the people while at the national level, the amount of food available could be a function of national production plus what is in stock and imports, including food aid, minus the quantity of exports, seed, feed, and post-harvest loss (FAO, IFAD, UNICEF, WFP and WHO, 2021, 2020; FAO, 2021). Quantitative food assessment is a vital first step in planning for food and nutrition security. In Kenya, fish is sourced from different distribution networks, starting with local small-scale fisheries (marine and inland), local fish markets, aquaculture production, and international imports. The goal of examining this dimension was to contribute to a broader understanding of Kenya's fish supply systems and to identify opportunities to increase the availability of nutritious fish as well as identify challenges in the pathways that need redress to improve the availability of fish.

1.2.2 Access

The access pillar of food and nutrition security refers to the economic, social, and physical means used to acquire food for an adequate diet at a level to ensure that satisfaction of other basic needs is not threatened or compromised; and that adequate food is reachable to everyone, including vulnerable individuals and groups (HLPE, 2020; Leroy *et al.*, 2015). Access may be examined at the personal, household, or community scale. I explore this dimension of food and nutrition security through the lens of a Theory of Access (Ribot and Peluso, 2003). Thence it was defined as the economic, social, and physical ability to derive nutritional benefits from fish including the rights associated with those abilities

(Ribot and Peluso, 2003). I delved into examining how coastal fishing communities interact to gain physical, social, and economic access or lack access to benefits from fish for food and nutrition security. This contributed to the identification of factors that enable and constrain access thus availing information and data to guide mainstreaming and transformation of small-scale fisheries for enhanced nutritional outcomes in coastal communities.

1.2.3 Agency

Agency refers to an individual or group having the capacity to act independently to make choices about what they eat, the foods they produce, how food is produced, processed, and distributed, and to engage in policy processes that shape food systems (HLPE, 2020; Clapp *et al.*, 2021; Gangas, 2016; Robeyns and Byskov, 2021; Manlosa, 2022). It is noteworthy that the protection of agency requires socio-political systems that uphold governance structures that enable the achievement of food and nutrition security for all (HLPE, 2020). To explore the agency pillar, I used the Capability Approach (Nussbaum and Sen, 1993; Sen, 1989, 1992, 1980), to reveal the existent personal, social and environmental conversion factors that act as conditions that underpin decisions that people make in obtaining fish for food and nutrition security. Understanding agency is important since it helps in diversifying interventions to meet multiple choices that people may be required to make based on their preferences and socio-economic status and thus supports efforts to overcome inequalities in the food system.

1.2.4 Utilization

Food utilization has been defined as an individual's dietary intake and ability to absorb beneficial nutrients contained in the food that is eaten (FAO, IFAD, UNICEF, WFP and WHO, 2023; HLPE, 2020). Food utilization relates to both the quantity of food that is eaten and the quality and diversity of the diet (Mahrt *et al.*, 2022; FAO, IFAD, UNICEF, WFP and WHO, 2023). Utilization also depends on having clean water, sanitation, and healthcare to reach a state of nutritional well-being where all physiological needs are met. This pillar is linked to the availability, access, and agency pillars such that when food is available and households have adequate access to it upon making decisions (agency) to obtain it, the next question is whether households are maximizing the consumption of adequate nutrition and energy (FAO, IFAD, UNICEF, WFP and WHO, 2023). Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, food preparation, dietary diversity and intra-household distribution of food, and access to clean water, sanitation and healthcare (FAO, IFAD, UNICEF, WFP and WHO, 2023). The utilization pillar was examined using household level surveys to assess how fish consumption and sociodemographic factors, including access to sanitation and clean water, influenced dietary diversity, dietary patterns, and food insecurity (the latter 3 were used as proxies of human health outcomes). This enabled me to provide an understanding of how household sociodemographic factors influence fish consumption, dietary patterns, and food insecurity.

1.2.5 Stability

Stability refers to the ability to ensure food security in the event of sudden shocks such as an economic, health, conflict, or climatic crisis or cyclical events like seasonal food insecurity (HLPE, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2023). Here, the focus is on what happens to households or individuals' livelihoods when hit by temporary negative shocks. These include the immediate effect of these negative shocks (vulnerability) and whether households can recover easily or whether they are pushed into a poverty trap from which recovery is laborious or even impossible (resilience) (Pieters et al., 2013). Stability issues may include short-term instability (which can lead to acute food insecurity) or medium to long-term instability (which can lead to chronic food insecurity) and climatic, economic, social and political factors can all be a source of instability (FAO, IFAD, UNICEF, WFP and WHO, 2023). There is a need to ensure stability in access to, availability of, and utilization of nutritious foods (Cuenca *et al.*, 2023). This pillar of food and nutrition security cuts across the preceding four pillars and is applied in this thesis to provide recommendations for governance and management that ensure achievement of availability, access, agency, and utilization that takes cognizance of shocks to the food system. This is done by identifying potential policy intervention areas that can be improved to ensure adaptation, and coping mechanisms associated with such shocks to stability. For instance, the temporal analysis of fish supplies (Chapter 2) and what this implies for management reflects how maintaining fish species diversity is key to meeting the stability of nutrient supply from small-scale fisheries.

1.2.6 Sustainability

Sustainability of a food system refers to the situation where the practices that contribute to the long-term regeneration of natural, social, and economic systems, ensure the food needs of the present generations are met without compromising the food needs of future generations (HLPE, 2020). This pillar, together with access are the recent additions to the definition of food security and both are reinforced in conceptual and legal understandings of the right to food (FAO, IFAD, UNICEF, WFP and WHO, 2023). Like the stability pillar, sustainability traverses the other four pillars with food systems expected to deliver food and nutrition security for posterity. In this thesis, I identify needed management interventions that can be leveraged to transform the aquatic food systems to achieve nutrition-sensitive governance for the benefit of the present and future generations. For example, drawing from the findings of Chapter 2, I highlight the need for improved fisheries management to ensure that wild fish stocks (especially nutrient-dense species) are rebuilt since their nutrient supply may not be replaceable by aquaculture and imports, thus posing a threat for future nutrient needs (sustainability).

1.3 Theoretical frameworks and methodological approach

This PhD study was set within a theoretically robust and interdisciplinary approach to guide my assessment of the various factors that influence the use of fish generally and tropical small-scale fisheries specifically as a promising frontier for food and nutrition security. This was found necessary because the fishery system is a complex social-ecological system (Ostrom, 2009; McGinnis and Ostrom, 2014; Binder *et al.*, 2013). This renders small-scale fisheries food systems as characteristically interdisciplinary since they involve multiple interactions between human and natural components (Allen and Prosperi, 2016). Consequently, this study incorporated an assessment of ecological (fish catches), nutritional (macronutrients and micronutrients), health (dietary patterns and food insecurity), and socio-economic aspects of fish and tropical small-scale fisheries through the integration of quantitative and qualitative social and physical science methods. Four theoretical frameworks guided the study: 1. Sustainable food system framework (HLPE, 2017; Van Berkum *et al.*, 2018; HLPE, 2020), 2. A Theory of Access (Ribot and Peluso, 2003; Myers and Hansen, 2020; Peluso and Ribot, 2020), 3. the Capabilities Approach (Sen, 1989; Alkire, 2005; Nussbaum and Sen, 1993; Nussbaum, 2013; Nambiar, 2013), and 4. Theory of change (HLPE, 2020; International Science Council, 2021) as described below.

1.3.1 Sustainable food system framework

I set out to examine the determinants of food and nutrition security within the bounds of the six pillars forming the basis for policy and governance within the sustainable food system framework defined by the FAO, High-Level Panel of Experts on food security and nutrition (HLPE, 2020). These six pillars were availability, access, agency, utilization, stability, and sustainability. The sustainable food system framework emphasizes the need to address the critical role of science and applied technologies to help deliver sustainable food systems (FAO, 2018; HLPE, 2022). It further envisages food systems that provide food and nutrition security for all without compromising the economic, social, and environmental bases to generate fish for food and nutrition security for future generations (HLPE, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2023). The framework includes the provision of sufficient, safe, healthy, nutritious, and affordable food that meets the nutritional needs of all as one of its key outcomes. The food systems framework further acknowledges the complexity of the relationships among the systems that support food production, food supply chains, food environments, the behaviors of individual consumers, diets, and nutritional and wider outcomes that feedback into the system (Sutcliffe *et al.*, 2023; Van Berkum *et al.*, 2018; Alarcon *et al.*, 2021). Therefore, I found this framework to be useful to guide my thesis research on establishing the contributions that fish can make to food and nutrition security in Kenya. In doing so I was able to identify possible interventions to transform Kenya's fisheries, food production, and trade policies to be more nutrition-sensitive. The course to transform Kenya's aquatic food system demands an understanding of what supports or undermines food and nutrition security, which this thesis attempts to unravel.

1.3.2 A Theory of Access

I applied a Theory of Access (Ribot and Peluso, 2003) to analyze the access dimension of food and nutrition security. A Theory of Access is useful to examine a broader notion of power to access (defined as the abilities of actors to gain or derive benefits from resources) (Ribot and Peluso, 2003). Access to resources arises within power structures constituting the material, cultural, and political-economic strands within the “bundles” and “webs” of powers (defined as the degree of control over material, human, intellectual, and financial resources exercised by different sections of society) that configure resource access (Peluso and Ribot, 2020; Hossain, 2017). A Theory of Access emphasizes the importance of diverse relations among actors and the resources they aspire to benefit from (Ribot and Peluso, 2003). A Theory of Access enabled the identification of relevant strands of power that Kenya’s coastal communities identified as important to gain access to fish for diverse uses. This was based on the mechanisms of access (defined as the means, processes, and relationships by which people are enabled to gain, control, and maintain access to resources) (Ribot and Peluso, 2003). The mechanisms of access are broadly composed of 1. rights-based access (legal and illegal access) and 2. structural and relational mechanisms of access (access to technology, access to capital, access to markets, access to labor and labor opportunities, access to knowledge, access to authority, access through social identity, and access via the negotiation of other social relations), that enable individuals, households or communities to gain, control and maintain access to resources (Peluso and Ribot, 2020; Ribot and Peluso, 2003). Therefore, the Theory of Access allowed me to reveal the mechanisms of the access dimension of the sustainable food system framework in a fish food system context based on local key informants’ perspectives.

1.3.3 Capabilities Approach

I drew from Amartya Sen’s Capability Approach (Sen, 1980, 1992, 1989) which emphasizes the set of valuable functionings (such as the ability to nourish oneself) based on human agency and the more substantive expansion of it by Nussbaum (Nussbaum, 2013; Nussbaum and Sen, 1993; Alkire, 2005; Ibrahim and Alkire, 2007) that sets out a comprehensive list of 10 human central capabilities (such as bodily health, life, other species and control over one's environment) to investigate conditions for agency among coastal communities. The Capability Approach helped me to examine the status and importance of local people's freedoms and choices in leading the life the individual(s) valued (Nambiar, 2013) in the pursuit of general wellbeing. By applying the Capability Approach, I delved into understanding the social-cultural and environmental dynamics of freedom and choices that people make to obtain fish for food and nutrition security. The Capabilities Approach calls for freedom to choose various things that a person values to do or to become. This enables the identification of the ability or lack thereof of people to provide for their individual needs and desires. Both Sen's and Nussbaum's framing indicates that choice is key to people turning their capabilities (positive freedoms, opportunities to achieve well-being) into functionings (actual realization of doings and beings). To Sen, people convert resources into capabilities, and capabilities into functionings based on their choices. Nussbaum expands on this by highlighting two types of capabilities, including combined capabilities, which are basic capabilities that people are born with, and internal capabilities, which are learned, trained, or developed. These capabilities must be operationalized under enabling, social, economic, and political, conditions to convert them into functionings based on people's choices (Nussbaum, 2013). In this thesis, I draw on Nussbaum's expanded capabilities approach to examine the conditions for agency (known in the capability literature as "conversion factors") that either enable or constrain coastal communities' capability to achieve food and nutritional security. Conversion factors are defined as conditions that influence whether an individual or individuals can convert or transform a resource into a functioning (Nambiar, 2013; Robeyns and Byskov, 2021). Consequently, I examined the environmental, social, and personal factors (Nambiar, 2013; Robeyns and Byskov, 2021; Robeyns, 2005) that influence whether people can convert their capabilities into functionings, as conditions for agency.

1.3.4 Theory of change

Throughout the four research chapters of this thesis (Chapter 2 – Chapter 5), I envisage the need for change (shift from existing undesirable conditions) in the status quo for Kenya to transform the nation's aquatic food systems to achieve food and nutrition security. Transformation of food systems has become crucial to providing nutritious, safe, affordable, and sustainable diets for all (Raza *et al.*, 2020; Slater *et al.*, 2022; Lawrence *et al.*, 2015). The theory of change has a wide range of possible uses in developing, managing, and evaluating interventions proposed or recommended by research (Mayne, 2015). This PhD study was conceived during a period of concerted efforts towards the transformation of aquatic food systems to be sustainable and beneficial to deliver global goals and national commitments. Therefore I adopted the theory of change approach recommended by the high-level panel of experts on food and nutrition security (HLPE, 2020) to identify where findings from this research would be applied for change across the six interconnected pillars of food security. This theory of change recognizes four critical policy elements that need to be supported by an enabling research and governance environment: "(1) recognizing the need for radical transformation of food systems; (2) viewing food security and nutrition as a system interconnected with other systems and sectors; (3) focusing on hunger and all forms of malnutrition; (4) recognizing food security and nutrition as being context-specific and requiring diverse solutions (HLPE, 2020)". The theory of change modified in this thesis was the generation of missing yet key information that makes the potential of aquatic foods to deliver positive human nutritional status and other health outcomes empirically known to widen our understanding of food security and to adopt a nutrition-sensitive approach to fisheries governance for food and nutrition security. Across all four research chapters, I endeavored to reveal existing gaps, provide empirical evidence, and propose recommendations that policy interventions can consider towards meeting fish food system transformations at local, subnational, and national scales in Kenya, that could be applicable at regional, and global scales.

1.3.5 Methodological approach

This thesis drew upon mixed methods to address the four research questions. I used data gathered from multiple sources including secondary fisheries catch assessment survey data, human population data, fish nutrient content information and data and primary market survey data, qualitative social survey data, and mixed quantitative and qualitative household survey data. The interdisciplinary nature of this thesis necessitated drawing from various research methodologies and methods that are specifically described in each respective research chapter (Chapters 2-5).

1.4 Contribution of the thesis

This thesis provides for the first time a detailed interdisciplinary case study of the interplay of factors associated with how people can benefit from using fish to tackle nutrient deficiencies in Kenya, that could be applicable elsewhere. The research avails the combined nutrient content and density information for fish consumed in Kenya and highlights the need to target vulnerable human populations such as children under five years to achieve desired nutrition outcomes through a multisectoral approach. I reveal the role of the different market traders and their potential contribution to supporting access and availability of nutritious fish at the subnational level. The study unravels the community-level social processes and power dynamics that influence access and agency highlighting potential policy levers to improve food and nutritional security. Furthermore, the study exposes the role of fish as the main animal-sourced food in the diets of coastal communities and how it was associated with health outcomes. This thesis contributes empirical data and information that is key to fitting the missing link of the identified multiple determinants that are essential to unlocking the potential of small-scale fisheries in Kenya's fight against nutrient inadequacies and general food insecurity.

1.5 Research aim, questions, objectives, and thesis outline

Fig. 1.1 presents a summarized conceptual framework that guided this thesis research. A holistic investigation of the potential contribution of fish to food and nutritional security towards tackling nutrient deficiencies using tropical small-scale fisheries in Kenya has not been described. Drawing from the theoretical frameworks described (Sections 1.3.1 - 1.3.4), this thesis aimed to examine how fish can support food and nutritional security in Kenya, across the six pillars of food security (availability, access, agency, utilization, stability, sustainability), and focusing on tackling nutritional deficiencies among vulnerable populations (such as children under five years and rural resource-scarce communities). My thesis sought to address four key questions related to the availability, access, agency, utilization, stability, and sustainability of fish and tropical small-scale fisheries to meet food and nutrition security:

1. *How much fish is <u>available</u> for food and nutrition security in Kenya, and what contribution do the different fish supply sectors (i.e., marine, freshwater, aquaculture, and imports) make?* (addressed in Chapter 2)
2. *What role do subnational fish markets play in mediating fish <u>availability</u> and <u>access</u> within the coastal context?* (addressed in Chapter 3)
3. *How do social processes and power dynamics (socio-cultural practices, attitudes, beliefs, markets) influence different people's <u>access</u> to fish, and their <u>agency</u> to acquire sufficient quantities of nutritious, and culturally appropriate seafood within coastal communities?* (addressed in Chapter 4)
4. *How do household fish consumption and socio-demographics influence the contributions fish make to human health (<u>utilization</u>), and what are the successful coping mechanisms?* (addressed in Chapter 5)

To answer these questions, four related and specific research objectives were set in the context of fish supply and tropical small-scale fisheries in Kenya. I set out to:

1. Quantitatively assess the available supplies of fish for food and nutritional security in Kenya. This included examining quantities of fish production across existing supply systems and an assessment of the nutrient content and nutrient density of fish from the different supply pathways.
2. Evaluate the coastal fish markets to determine their role in facilitating the availability and accessibility of nutritious fish for food and nutrition security.
3. Examine the factors shaping access to and agency about fish for food and nutrition security in coastal communities.
4. Investigate how household fish consumption and sociodemographic factors influence health outcomes (dietary diversity, dietary patterns, and food insecurity).

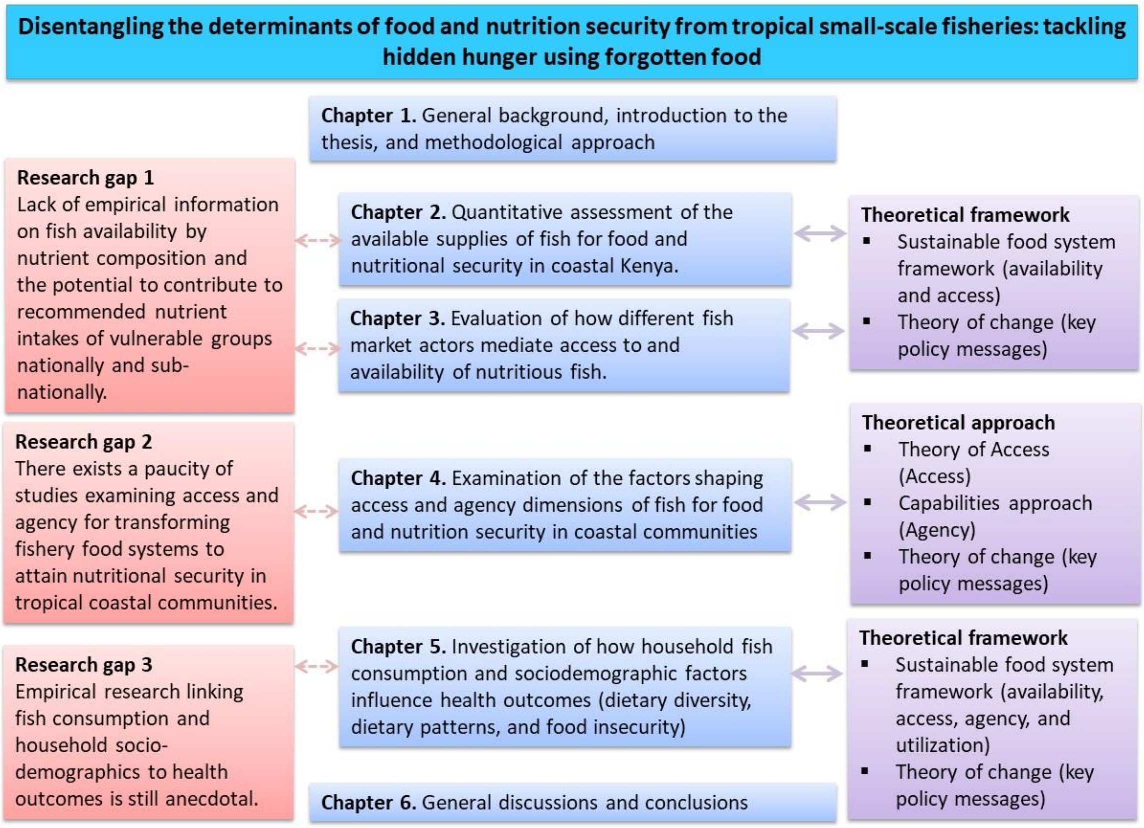


Figure 1.1 The PhD thesis research conceptual framework for the investigation of the determinants of food and nutrition security from tropical small-scale fisheries in Kenya

This thesis is organized into six chapters: In **Chapter 1** (this chapter), I put the study into context and present background information on how fish and tropical small-scale fisheries currently contribute to food and nutrition security, what the potential contributions could be and identify the key gaps in data and knowledge. I present the research theoretical frameworks and summary of the methodological approach, thesis aims, research questions and objectives, and the contribution this thesis makes to fill the identified gaps.

In **Chapter 2,** I present a quantitative assessment of the available stock of edible fish for food and nutritional security in Kenya. I establish the fish supply quantities and nutrient concentrations available from the fish and fish supply sources (marine, freshwater, aquaculture, and import). I compile nutrient information on all fish species in Kenya to quantify their potential contribution of nutrient supplies to the national population and evaluate how changes to supply might impact food and nutrition security.

Drawing from the findings in Chapter 2, where I established that fish has high potential to contribute to food and nutrition security in communities within 20 km of fishery water bodies, in **Chapter 3**, I examine how the subnational fish markets mediate availability and access to fish in the coastal subpopulations. This follows the understanding that the trade of fish plays an important role in food and nutrition security in developing countries (FAO, 2022b). However, how fish trading by different market actors influences people's abilities to acquire nutritious food that supports food and nutrition security outcomes in the coastal subpopulation has not been researched. I evaluate how people may benefit from traded fish and identify how markets influence the availability and access to fish at the coastal scale.

Noting that fish consumption may be influenced by an interplay of factors beyond fish supply and fish trade (Monterrosa *et al.*, 2020; Ayuya *et al.*, 2021), in **Chapter 4**, I examine the factors shaping access to fish and people's agency to acquire nutritious food that supports food and nutrition security in coastal communities. Using in-depth key informant qualitative interviews, I identify how different people can access benefits from fish and identify what social processes and power dynamics influence access and agency in the coastal communities. I explore key socio-economic, governance, and fishery characteristics (i.e., institutions, rules, social norms, preferences, taboos, and beliefs) that shape food access and agency.

To further understand the linkages between fish consumption and utilization pillar, in **Chapter 5**, I investigate the fish consumption and household socio-demographic factors that influence health outcomes (dietary diversity, dietary patterns, and food insecurity). Here, I use mixed qualitative and quantitative household assessment surveys, conducted in three coastal communities, to quantify the key factors associated with health outcomes. Surveys were conducted with household members in charge of the preparation of meals (or caregivers). The nutritional outcomes were established by examining dietary diversity, dietary patterns, and food insecurity as proxies of health outcomes.

In **Chapter 6,** I provide a synthesis of the thesis into a final discussion, conclusions, and recommendations that could inform present and future developments of integrated approaches between fisheries production, fish supplies, food, and nutrition security. I highlight where multisectoral management and governance strategies that link fishery production with sustainable improvements in fish for food and nutrition security may be leveraged by developing a modified theory of change framework, in which I identify where interventions are needed to operationalize the new evidence from this thesis to support the six pillars of food and nutrition security.

Chapter 2. Fish contributions toward nutritional security in Kenya

2.1 Abstract

Nutrient deficiencies remain prevalent globally and are particularly common in low- and middle-income countries, such as Kenya, where fish holds the potential to help address these deficiencies but remains barely incorporated in nutrition policies and strategies, partly due to a lack of supporting evidence. I address this gap by analyzing sixteen years of fisheries production and trade data from marine, freshwater, and aquaculture systems to evaluate fish nutrient supply, assess changes in supply, and determine the contributions the current supply could make to meet the nutritional needs of children under five years. The findings show that despite an 11% increase, through time, in the total supply of fish, there was a 24% decline in per capita fish consumption due to fishery changes and human population growth. Furthermore, a 21% decline in the supply of fish from inland freshwater systems resulted in a 25-40% decline in nutrient supply. Based on the current supply of fish, Kenya’s per capita consumption of 2.5 kg is below the World Health Organization (WHO) recommendation of 10.4 kg/yr. However, this supply has the potential to support nearly 13 million Kenyans (24% of the population) at this WHO recommendation. If supply was targeted towards vulnerable groups, such as children under five years, it could supply all children in Kenya with one-third of their calcium, selenium, and protein and over 70% of children in Kenya with one-third of their iron, zinc, and omega-3 polyunsaturated fatty acids (PUFA) requirements. Therefore, fish can play an important role in supporting nutritional security in Kenya but would require that strategic interventions involving all relevant sectors are considered to reduce identified nutrient deficiencies.

Published - Omukoto, J.O., Graham, N.A. & Hicks, C.C. (2024) Fish contributions toward nutritional security in Kenya. Food Security. https://doi.org/10.1007/s12571-024-01459-8

2.2 Introduction

The availability of sufficient quantities of essential micro and macronutrients is key to supporting people's health. While global food production has the potential to supply sufficient quantities of food to meet nutrient requirements, access has not been equally met, causing malnourishment and famine, despite over 40 years of international efforts to address these (Chappell and LaValle, 2011; FAO, 1974). Inadequate access to nutritious food is most persistent across Sub-Saharan Africa (Muringai *et al.*, 2022; Slater *et al.*, 2022; White *et al.*, 2021), resulting in a high prevalence of stunting, and other forms of malnutrition (Béné et al., 2010; Byrd et al., 2021; FAO, 2021; Ruel & Alderman, 2013). During 2020-2022, 72% of the total population in Kenya experienced moderate or severe food insecurity with 28% experiencing severe food insecurity (FAO, IFAD, UNICEF, WFP and WHO, 2023). The situation is exacerbated by the fact that up to 74% (39 million people) of Kenyans are unable to afford a healthy diet (FAO, IFAD, UNICEF, WFP and WHO, 2023; Herforth *et al.*, 2020). The vulnerability to food insecurity in this region has been attributed to various factors including domestic challenges such as low socio-economic status, low investment in irrigated agriculture and research, and climate change effects (FAO, IFAD, UNICEF, WFP and WHO, 2023; Wudil *et al.*, 2022).

Food and nutrition security requires the maintenance of sufficient yields and a stable supply of nutritionally diverse foods (Bernhardt and O'Connor, 2021). Therefore, policy reforms for food and nutrition security improvement must have clearly defined nutrition attainment commitments. The government of Kenya has committed to ensuring that all citizens are free from hunger and have adequate food of acceptable quality as stipulated in the Constitution and the Food and Nutrition Security Policy (FNSP), 2011. The country has committed as a signatory to several nutrition-related global agreements and mechanisms including the United Nations (UN) Decade of Action on Nutrition (2016–2025), the Scaling Up Nutrition (SUN) movement, the World Health Assembly (WHA) 2025 nutrition targets, the Sustainable Development Goals (SDGs), and the Second International Conference on Nutrition (ICN2) Declaration and Plan of Action. These agreements have defined the foundation for addressing the immediate, underlying, and basic causes of malnutrition including expanding the political, economic, social, and technological space for nutrition actions (Nutrition International, 2021). All these commitments require empirical research and greater sharing of information among all sectors that are key to ensuring the availability and accessibility of nutritious food in the nation.

While fish has been recognized as a nutrient-dense food, and evidence of the positive impact of fish on human health at a global scale is prevalent in the scientific literature (Crona *et al.*, 2023; Golden *et al.*, 2021; Thilsted *et al.*, 2016), its contribution to national food and nutrition security remains uncertain in most countries (Chan *et al.*, 2019). As a result, there is a paucity of fisheries-related scientific information available to those developing management strategies and food security policy directions, particularly in tropical developing countries, thus marginalizing the role that fisheries and aquaculture can and should play in national food security and nutrition policies (FAO, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2022). This is in part due to limited data on the nutrient composition of fish species (Byrd et al., 2021; Nordhagen et al., 2020). To help address this limitation, the ability to estimate nutrient concentrations of different species of fish has recently been advanced (Hicks et al., 2019; MacNeil, 2021), and this information has been made publicly available through the FishNutrients tool in FishBase (Froese and Pauly, 2021). Using this information, many developing regions and emerging economies can gain empirical evidence to guide plans to use their fisheries resources to help address nutrient deficiencies.

Here, I quantify nutrient content and nutrient supply for marine and freshwater capture, aquaculture, imported and exported fish in Kenya, to determine the contribution fish can make to food and nutritional security. The objectives of the study were to: 1. Establish trends in the supply of fish over 16 years in Kenya (2005-2020); 2. Assess the nutrient content of current (2020 estimates) fish supply; and 3. Evaluate over time how the fish supply could contribute to nutrition security. Kenya was used as a case study due to a high prevalence of food and nutrition insecurity (FAO, IFAD, UNICEF, WFP and WHO, 2023), and its binding commitments to address this. Further, the importance of fish resources in Kenya has not been comprehensively incorporated into food security policy and strategies. I focus on children under 5 years, for whom micronutrient deficiencies remain a public health concern, with inadequate intakes of calcium, iron, zinc, vitamin A and animal-sourced protein (Byrd *et al.*, 2018; Codjia *et al.*, 2024; Kamau-Mbuthia *et al.*, 2023; Ryckman *et al.*, 2022; Stewart *et al.*, 2019) resulting in nearly one-third of children aged 6-59 months being anemic, 9.2% with Vitamin A Deficiencies (VAD) and the prevalence of zinc deficiency at 83.3% (Kenya Ministry of Health, 2011).

2.3 Materials and methods

2.3.1 Study sites

Kenya, in East Africa, lying between latitudes 4.5ºN and 4.5ºS and longitudes 34ºE and 41ºE (Fig. 2.1), is currently classified as a lower-middle-income country based on its per capita gross national income (GNI) of $2,080 for 2021 (United Nations, 2021). Kenya's population of over 50 million is growing rapidly at 2.3% (United Nations Department of Economic and Social Affairs, Population Division, 2019) with 13% of the population being children below five years of age.

Kenya's supply of fish comes from marine and freshwater wild capture fisheries, aquaculture, and imports. Kenya's freshwater wild captured fish comes from Lake Turkana, Lake Victoria, several small inland freshwater lakes, dams, and rivers (Schubert *et al.*, 2021). The marine capture fisheries come from the 9,700 km^2 of territorial seas and 142,400 km^2 of exclusive economic zone (EEZ) (Kimani *et al.*, 2018). Kenya's domestic aquaculture supplies come from an emerging aquaculture sector involving extensive, semi-intensive, and intensive production (Munguti *et al.*, 2021). Kenya is also focused on meeting the national demand for fish by increasing imports of mackerel and tilapia, largely from China, but also from Japan, Oman, Korea, Somalia, and Djibouti (Fish Inspection and Quality Assurance Report, 2020). Some imports also come from the neighboring East African countries of Tanzania and Uganda (Ibengwe *et al.*, 2022).

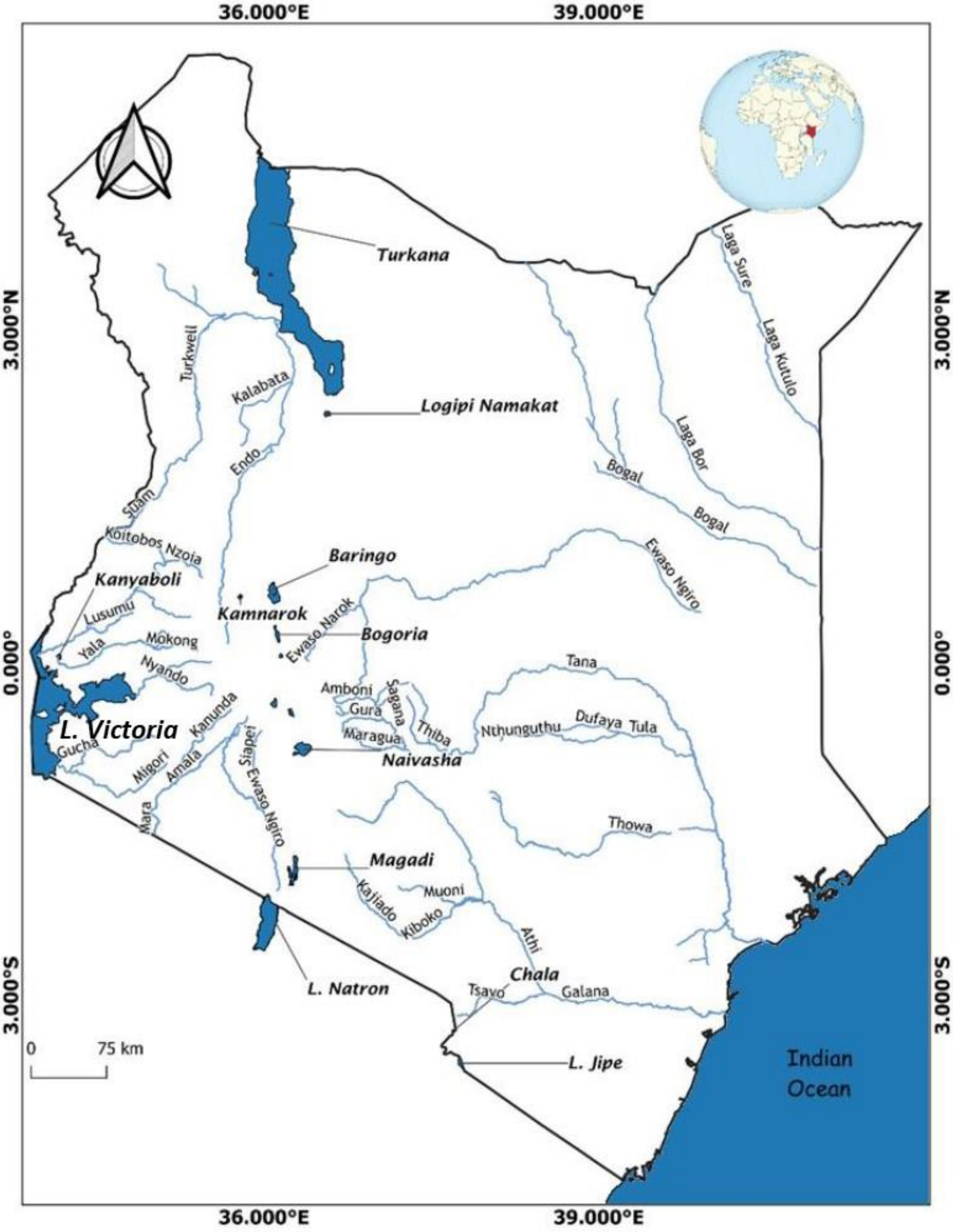


Figure 2.1 Map of Kenya showing the fishery water bodies (source: Fisheries Annual Statistical Bulletin, 2017)

2.3.2 Fish production data

The fish production data (landings, aquaculture, imports, and exports) that I analyzed was gathered from the national fisheries' statistical bulletins, Kenya National Economic Survey Reports, and the Fish Inspection and Quality Assurance Report, Coast edition (2020) (Table 2.1). These sources of data are produced and compiled by the Kenya Fisheries Service (KeFS). Data from 2016 was used to standardize fish families/categories to ensure that taxa groupings were consistent through the whole time series. The data from the sources were disaggregated into mixed categories of fish families and fish groups which were at species, genera, family, or broader grouping; thus, my calculations were limited to analysis of these mixed fisheries categories (henceforth referred to as "fish taxa" in the rest of this article). I therefore use the term fish to include all aquatic animals, including finfish, shellfish (molluscs and crustaceans) and other invertebrates (such as sea cucumbers) (FAO, 2022b). Due to COVID-19 restrictions during 2020, there may be some uncertainty associated with the data from 2020. The COVID-19 curfew affected many fishers who undertake night fishing as the timing of their fishing expedition was interrupted. The same was noted for fishers who leave early morning in search of baits when the curfew hours extended to 5:00 AM, yet this is the ideal hour for their bait searching (Kenya Fisheries Statistical Bulletin, 2020).

Table 2.1 Fish production data sources that were used in this study

Type of data	Sources	Timescale
Fish landings (Marine and Freshwater)	National fisheries statistical bulletins Kenya National Economic Survey Reports	2005-2016 2017-2020
Aquaculture	National fisheries statistical bulletins Kenya National Economic Survey Reports	2005-2016 2017-2020
Trade (exports and imports)	National fisheries statistical bulletins Kenya National Economic Survey Report Fish Inspection and Quality Assurance Reports, Coast edition (2020)	2005-2016 2017-2020 2020

2.3.3 Fish supply and fish consumption

To calculate the supply of fish available for human consumption, I first subtracted exported quantities from the reported supply quantities for the respective years and fish taxa to obtain the net supply of marine and freshwater capture quantities in Kenya. Among the imported species/taxa reported in Kenya include Sphyraenidae (frozen barracudas), frozen mixed fish and fish products, Scombridae (frozen mackerels), Salmonidae (frozen salmon and sea trout), and Cichlidae (tilapias) while exports include the taxa Sciaenidae (drums or croakers), Latidae (Nile perch), Lutjanidae (snappers), Lethrinidae (emperors), Serranidae (groupers), Haemulidae (grunts), Scombridae (tunas and mackerels), Carangidae (kingfishes), Engraulidae (anchovies), Istiophoridae (billfishes), Sharks & Rays, Palinuridae (lobsters), Portunidae (crabs), Penaeidae (shrimps/prawns), Octopodidae (octopus) and Loliginidae (squids). I then calculated the total supply of fish by summing the net supply from inland freshwater systems, coastal and marine systems, aquaculture, and imports (Lofstedt *et al.*, 2021). I multiplied the net weights of fish supply data (capture, aquaculture, imports, and exports) by established edible portion conversion factors for finfish, molluscs, and crustaceans, which represent the portion remaining after gutting and deboning (Table 2.2 in Appendix 1) (Edwards *et al.*, 2019; Thurstan and Roberts, 2014). Fish that are consumed whole (e.g., small pelagic species) or that were reported as processed products (e.g., fillets) were assigned a conversion factor of 1 (Table 2.2 in Appendix 1).

Next, to calculate the apparent consumption of fish (per capita fish supply), the total supply of fish was divided by Kenya's total human population for the applicable year to establish the per capita fish supply. The annual Kenya population estimates for 2005 - 2020 were obtained from the UN (United Nations Department of Economic and Social Affairs, Population Division, 2019) who conduct demographic research, support intergovernmental processes in the area of population and development, and assist countries in developing their capacity to produce and analyze population data and information.

I evaluated the change in the supply of fish across all landed taxa through time. The time-series did not meet the main assumptions for fitting a trend line by linear regression (assumption of linearity, homogeneity of variance, independence of errors, normality of errors, and no multicollinearity). Therefore, I used the nonparametric Mann-Kendall (MK) trend test (a non-parametric approach to time-series data analysis), followed by the Thiel-Sen estimator or Sen's Slope test to determine and fit the trend's slope to examine whether the changes in trends in total supply, and per capita supply over 2005-2020 were significant (Aditya *et al.*, 2021; Chen *et al.*, 2020; Helsel *et al.*, 2020).

2.3.4 Nutrient content of available fish and nutrient supply

This analysis focused on the concentration of five key micronutrients (calcium, iron, selenium, vitamin A, and zinc) and two macronutrients (total omega-3 PUFA and protein) across the fish taxa reported in the statistical bulletin reports. These nutrients were chosen because they are known to be lacking in diets in East Africa, yet rich in fish (Hicks *et al.*, 2019; Ngare and Muttunga, 1999; White *et al.*, 2021). Estimates were sourced for these nutrients from FishBase (Froese & Pauly, 2021; Hicks et al., 2019; MacNeil, 2021). Where data were reported to species level, species nutrient values were taken directly from FishBase. Where data was reported at the broader fish taxa level, I used the average nutrient values across species in that fish taxa that were found in Kenya's geographical region on FishBase. For non-finfish species (molluscs, crustaceans, sea cucumbers), where there are fewer data and species-specific estimates, nutrient values were obtained from the Food and Agriculture Organization's International Network of Food Data Systems (INFOODS) (Anon, 2021a, Anon, 2021b) based on estimates averaged to the lowest taxonomic unit. I used the preceding nutrient information to develop a national fish nutrient content database for the 52 consumed fish taxa reported in the most recent (2020) statistical bulletin in Kenya (Table 2.3 in Appendix 1). I further used this nutrient information data to calculate the nutrient supply (amount of each nutrient available in Kenya from the fish supplies) by multiplying nutrient content per 100 g of each fish taxon by the total weight of each fish taxon. I then calculated the nutrient supply from the four sources (marine fisheries, freshwater fisheries, aquaculture, and import) by summing up the nutrient supply of fish within each source.

I examined the correlative associations among the seven nutrients for all the currently supplied 52 fish taxa using principal component analysis (PCA) (Kassambara, 2017). PCA was used to identify relative associations among the fish taxa and nutrient types and examine the significance of the contribution of the nutrients on the principal axes of the associations. This approach helped identify the principal directions in which the nutrient content data varied, and where similarities and differences between fish taxa occurred. PCA factors with eigenvalues greater than 1, and which the scree plot indicated a break or elbow cut-off were used to identify patterns in nutrient content among fish taxa (Kassambara, 2017).

2.3.5 Nutrient density of fish supply

I calculated the nutrient density of each fish taxa recorded in Kenya's fish supply data based on the nutrient content of each fish taxa relative to established recommended nutrient intake values. Nutrient density was defined and calculated as the contribution a 100 g portion of fish (Drewnowski, 2009) would make towards the recommended nutrient intakes (RNI) of a target population group (in our case, children under 5 years) (Hicks *et al.*, 2021; Maire *et al.*, 2021). I used per 100 g as a standard unit used for nutrient composition on FishBase, FAO INFOODS database, and the Kenya Food composition tables. Targeting children under five years was considered an appropriate strategy since interventions that improve early nutrition have the potential to improve outcomes throughout life (Black *et al.*, 2020; Heidkamp *et al.*, 2021). Nutrient density is therefore the sum of the percentage contribution that a 100 g of raw fish makes to the recommended nutrient intake across all seven nutrients (calcium, iron, selenium, vitamin A, zinc, omega-3 PUFA, and protein) (Maire *et al.*, 2021). The percentage contribution to RNI for each nutrient was capped at 100% to prevent extreme values from dominating patterns of variation in density scores such as fish sources or fish taxa with especially high values for some nutrients such as protein and selenium (Maire *et al.*, 2021). Nutrient density scores can therefore scale up to a maximum potential value of 700%, where all 7 nutrients are fulfilling recommended nutrient intakes. I calculated the weighted average of nutrient density across all reported fish taxa in 6 categories representing each source (marine and freshwater capture, aquaculture, and imports) as well as exports (marine and freshwater), and across the 20 top taxa (7 freshwater and 13 marine).

The Kenya country-level information on nutritional intakes has been reported qualitatively based on the significance of micronutrients and macronutrients to human development. Therefore, there are no nutrient-specific quantitative recommendations except for overall animal protein intakes (Ministry of Health, 2017). To overcome this limitation, estimations of the RNI for children aged under 5 years were based on the recommended values by the FAO and WHO (FAO/WHO, 2004) for micronutrients, recommended intakes by the Institute of Medicine (Institute of Medicine, 2006) for protein adequate intakes (AI) and RNI for total omega-3 PUFA adequate intakes based on the FAO (FAO, 2010) (Table 2.4 in Appendix 1).

For each of the 84 taxa reported in the entire 2015-2020 dataset, I calculated the amount or portion size of fish in grams that would be required to meet an average of 33.3% of the recommended nutrient intake across the six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 PUFA) for a child under five years old (Beal, 2020; Hicks *et al.*, 2021; White *et al.*, 2021). The contribution of each nutrient is capped at 100%, such that an average of 33% of requirements can be met by two nutrients providing 100% of the requirement or six nutrients providing 33.3% of the requirements (Beal, 2020; White *et al.*, 2021). I then present the number of taxa, and the biomass of supply across the portion sizes, and what proportions of these are drawn from taxa originating from inland freshwater systems versus coastal and marine systems.

2.3.6 Changes in fish and nutrient supply and potential contributions to nutritional security

To examine changes in fish supply, nutrient supply, and apparent consumption, I used 2005 as a reference year, and 2020 as our most recent year for which there was supply data and calculated percent change in fish supply, nutrient supply, and apparent fish consumption using the equation:

$$Percent\ change = \frac{Fish\ supply\ in\ 2020 - Fish\ supply\ in\ 2005}{Fish\ supply\ in\ 2005} * 100$$

I substituted the fish supply in the above equation with per capita fish consumption and nutrient supply, to get the change in apparent consumption and nutrient supply respectively. Nutrient supply was calculated by multiplying nutrient content of fish taxa by weight of production. To determine the potential contributions of the available fish supply to the Kenyan population, I divided the available fish supply by the recommended per capita consumption of 10.4 kg/yr based on WHO recommended intake of regularly eating 1-2 servings of fish per week. I used 100 g as the standard serving and 52 weeks per year to get 10.4 kg/yr. To estimate the potential contributions of the available fish supply to the Kenyan population residing within 20 km of the inland and marine fisheries water bodies, I assumed that 20.4% of Kenya's population was residing within 20 km of inland and marine fishery water bodies (Robinson *et al.*, 2022c) and therefore divided the available fish supply by this population. To assess the potential contribution to nutrition security of the available nutrient supply, I divided the available supply of each nutrient by the nutrient needs of our target population. I focused on children under five years of age and assumed that one-third of their recommended nutrient intake would come from fish, to establish how many children could have 33% of their nutrient needs met by the current supply (Ortenzi and Beal, 2021). All the data analyses were completed in the freely available R and RStudio software (R Core Team, 2022; RStudio Team, 2020).

2.4 Results

This study is the first to analyze and present combined fish nutrient content data, nutrient density, and portion size requirement to meet 33% of needs for six nutrients and examine changes in fish-derived nutrients from tropical marine, freshwater, aquaculture, and imported fish in Kenya. I frame this in the context of targeting malnutrition among children under five years who are vulnerable to nutritional inadequacies at such a critical developmental stage.

2.4.1 Trends in the supply of fish

Most of the supply of fish in 2020 came from inland freshwater systems (90,783 tons representing 67% of total supplies), followed by coastal and marine systems (19,179 tons representing 14% of supplies), aquaculture (17,352 tons representing 13% of fish supply), and finally imports (8,430 tons representing 6%

of the supply quantities) (Fig. 2.2 a). Between 2005 and 2020, the supply of fish from inland waters declined by 21% (Fig. 2.2 a). This decline was compensated for by increases in coastal and marine systems, aquaculture, and imports, resulting in an overall 11% marginal increase (p = 0.048) of fish supply (Fig. 2.2 a, b). However, this compensation for the decline in inland freshwater supply did not translate into adequate fish supplies to meet the national per capita supply, which declined significantly (p = 0.015) by 24% from an estimated 3.3 kg/capita/year in 2005 to 2.5 kg/capita/year in 2020 (Fig. 2.2 c). The national population grew from an estimated 37 million people in 2005 to about 54 million people in 2024 (Figure 2.3).

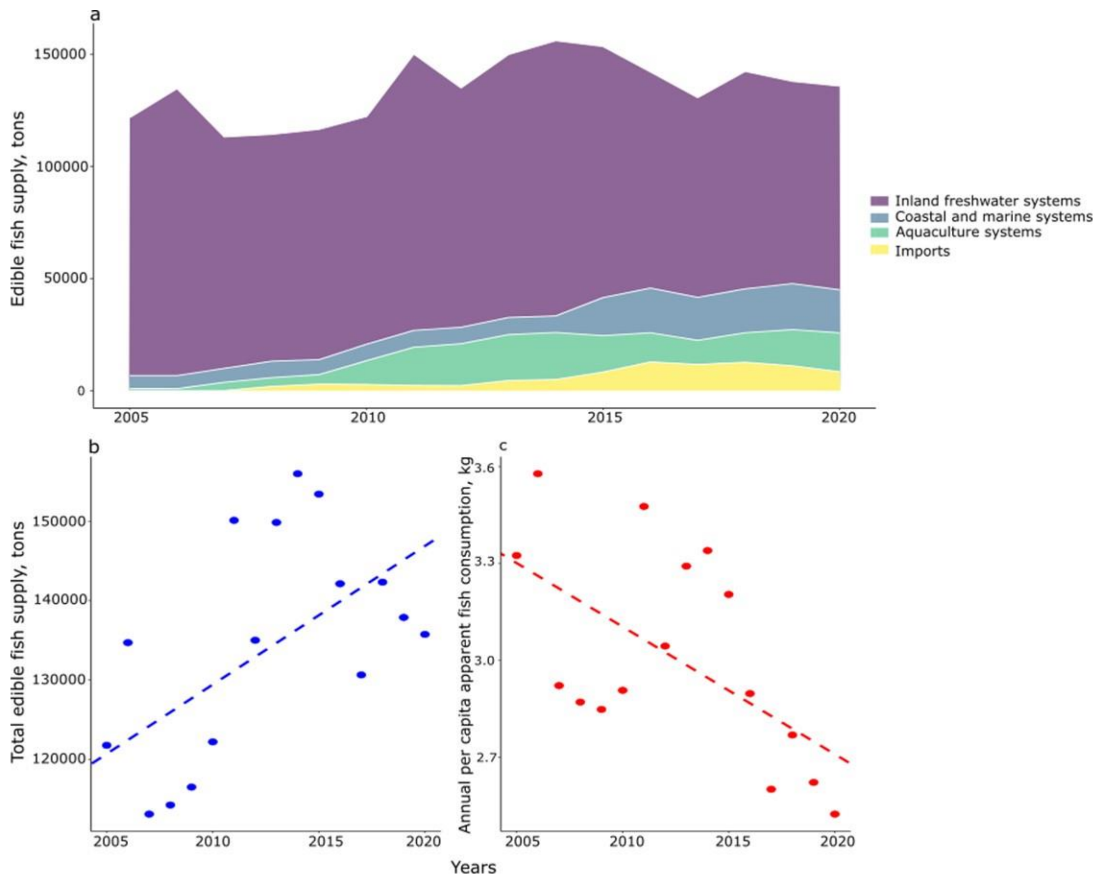


Figure 2.2 Supply of fish in Kenya, a - disaggregated by sector (inland freshwater capture fisheries, coastal and marine capture fisheries, aquaculture, and imports) b - as total supply of edible fish (nonparametric Mann-Kendall (MK) trend test, p=0.048), and c - as apparent per capita fish consumption (nonparametric Mann-Kendall (MK) trend test, p=0.015). Data sources: Kenya Fisheries Service Statistical Bulletins, Fish inspection and quality assurance reports, and Kenya National Bureau of Statistics Economic Survey Report 2021

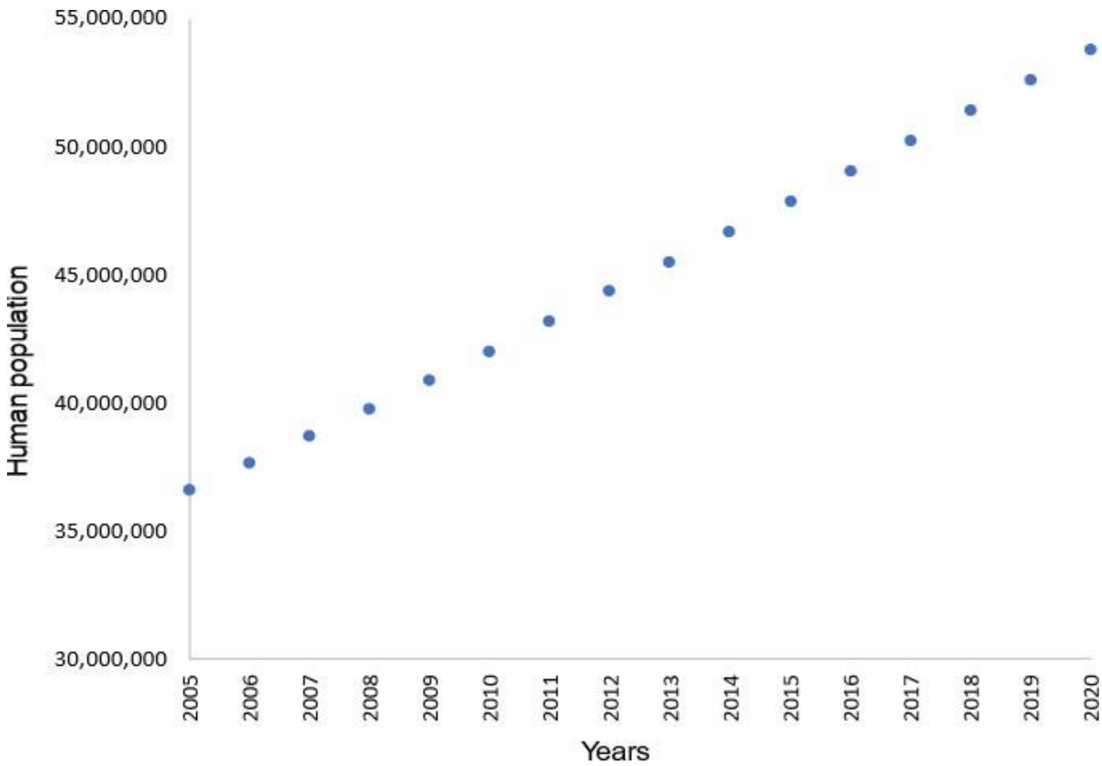


Figure 2.3 Human population trend in Kenya during 2005-2020. Data sources: United Nations, Department of Economic and Social Affairs, Population Division (2019)

2.4.2 Nutrient content of the available fish

The nutrient content of fish varied widely across taxa with an indication of overlaps of inland freshwater-derived and marine water-derived taxa except for the families Danionidae (locally called “omena”) and Salmonidae (trout) (Fig. 2.4). The larger overlap of fish taxa at the centre of the PCA plot reflects the similarity in nutrient contents of these fish per 100 g portion size. Fish taxa at extreme directions of the nutrient arrows imply a high content of specific nutrients per 100 g portion size.

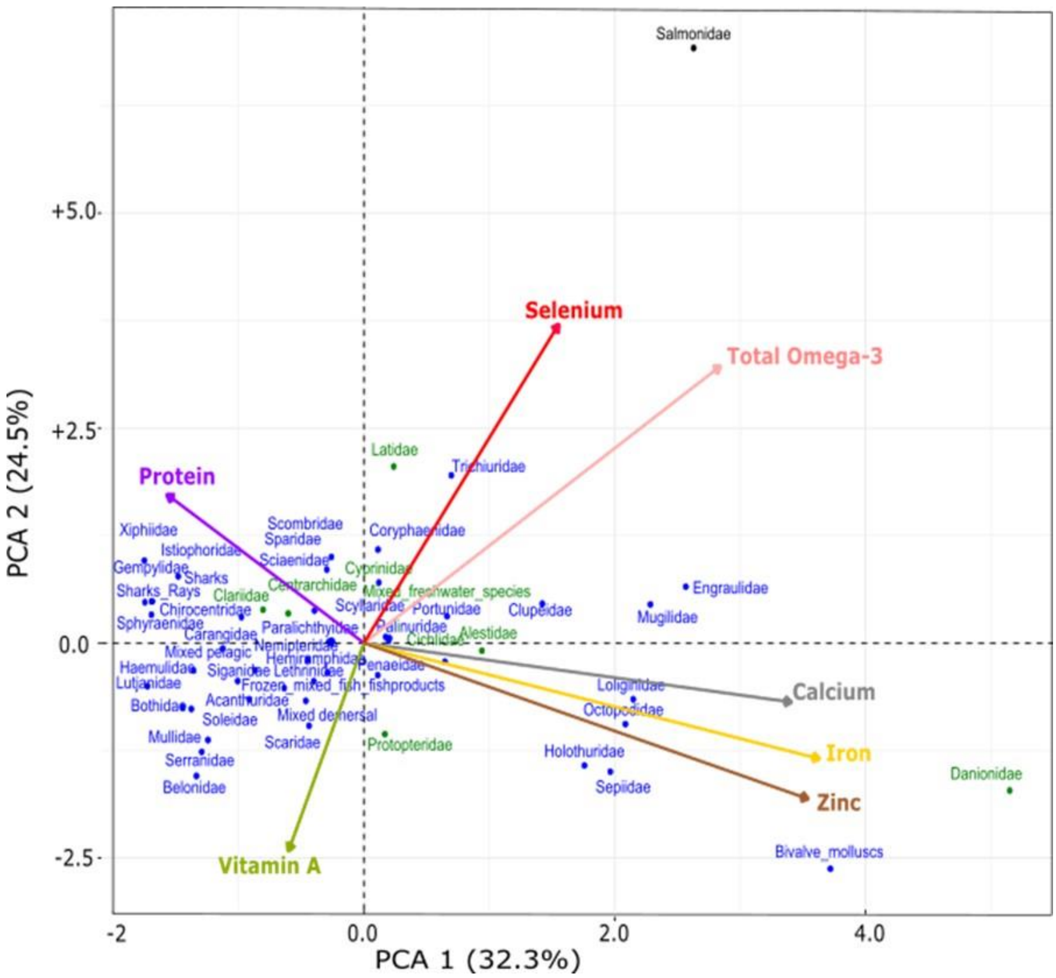


Figure 2.4 Principal Component Analysis (PCA) of the nutrient content across 7 nutrients among the 52 fish taxa reported in the Kenya fisheries statistics. Fish taxa in green refer to those of freshwater origin while those in blue refer to those from coastal and marine waters, Salmonidae is sourced from aquaculture

Principal component analysis (PCA) of all 52 fish taxa revealed three nutrient content patterns (Fig. 2.5 a, b, c). The three nutrient content patterns together explained up to 72.4% of the variation in the nutrient content. Table 2.5 in Appendix 1 shows the statistical significance of the nutrients with high factor loadings on each of the three PCA axes representing the nutrient content patterns. The first nutrient content pattern identified fish that were high in calcium, iron, selenium, zinc, and total omega-3 PUFA, and accounted for 32.3% of the variance. This nutrient content pattern was associated with freshwater cyprinid (Danionidae), bivalve molluscs, rainbow trout (Salmonidae), anchovies (Engraulidae), mullets (Mugilidae), squids (Loliginidae), octopuses

(Octopodidae), cuttlefishes (Sepiidae), sea cucumbers (Holothuridae) and swordfish (Xiphidae) as the first 10 fish taxa with greatest PCA factor loadings. The second nutrient content pattern revealed fish that were rich in selenium, total omega-3 PUFA, and protein, accounting for 24.5% of the variation. This nutrient pattern was associated with rainbow trout (Salmonidae), bivalve molluscs, Nile perch (Latidae), whiptails (Trichiuridae), freshwater cyprinids (Danionidae), needlefishes (Belonidae), cuttlefishes (Sepiidae), sea cucumbers (Holothuridae), groupers (Serranidae) and goatfishes (Mullidae). The third nutrient content pattern was associated with calcium, zinc, and protein, and explained 15.6% of the variation. The top 10 fish taxa with the greatest PCA factor loadings this pattern included lungfish (Protopteridae), bivalve molluscs, Danionidae, Salmonidae, Belonidae, Engraulidae, Portunidae, Palinuridae, Scyllaridae and Sepiidae.

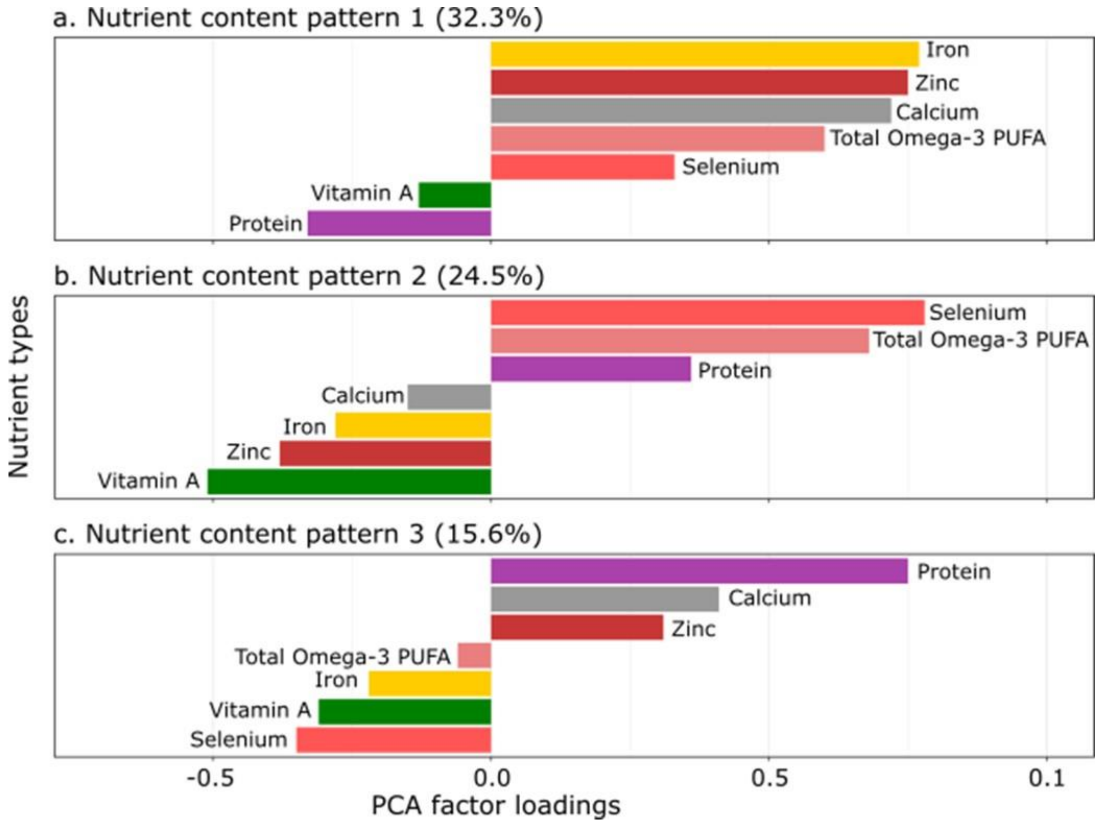


Figure 2.5 Principal Component Analysis (PCA) derived fish nutrient content patterns from the 52 fish taxa, a - Fish nutrient content pattern 1, b - Fish nutrient content pattern 2, c - Fish nutrient content pattern 3

2.4.3 Nutrient density of targeted fish by source and taxa

The nutrient density of an average fish varied by source (i.e., marine and freshwater capture, aquaculture, imports, and marine and freshwater export) (Fig. 2.6a). An average 100 g fish serving from any of the sources has the potential to meet all the selenium and protein dietary requirements for a child under 5 years (Fig. 2.6a). Fish from the inland freshwater systems have the highest nutrient densities. An average 100 g serving has the potential to meet over 45% of the nutrient needs for a child under 5 years across all nutrients except vitamin A, with a potential calcium contribution of 90%, and total omega-3 PUFA contribution of 64% (Fig. 2.6a). The coastal and marine systems, aquaculture, imports and exports have the potential to support over 25% fulfillment of recommended intakes for iron, selenium, zinc, total omega-3 PUFA, and protein.

An average 100 g serving of fish from all the 20 most abundant fish taxa by edible weight has the potential to fulfill the selenium and protein requirements for an under 5 years old child but varied in contributions to other nutrients (Fig. 2.6b). Seven of these fish taxa were from inland freshwater systems while 13 were coastal and marine fishes. Family Danionidae, which consists of one species, the freshwater silver cyprinid (*Rastrineobola argentea*) had the highest nutrient density, with a 100 g serving providing over 60% to the recommended intake of all nutrients except for vitamin A where it contributed 19%. Furthermore, a 100 g serving of this freshwater silver cyprinid could meet 100% of the recommended intake of calcium for children under 5 years. Among the coastal and marine species, octopus had the highest nutrient density followed by the clupeids (mainly sardines). Two marine fish families, namely Belonidae (needlefishes) and Lutjanidae (snappers) were found to contribute over 25% to vitamin A requirements, higher than the other taxa. The different fishes contributed to some degree to different nutrients and therefore hold some potential to contribute to recommended nutrient intakes.

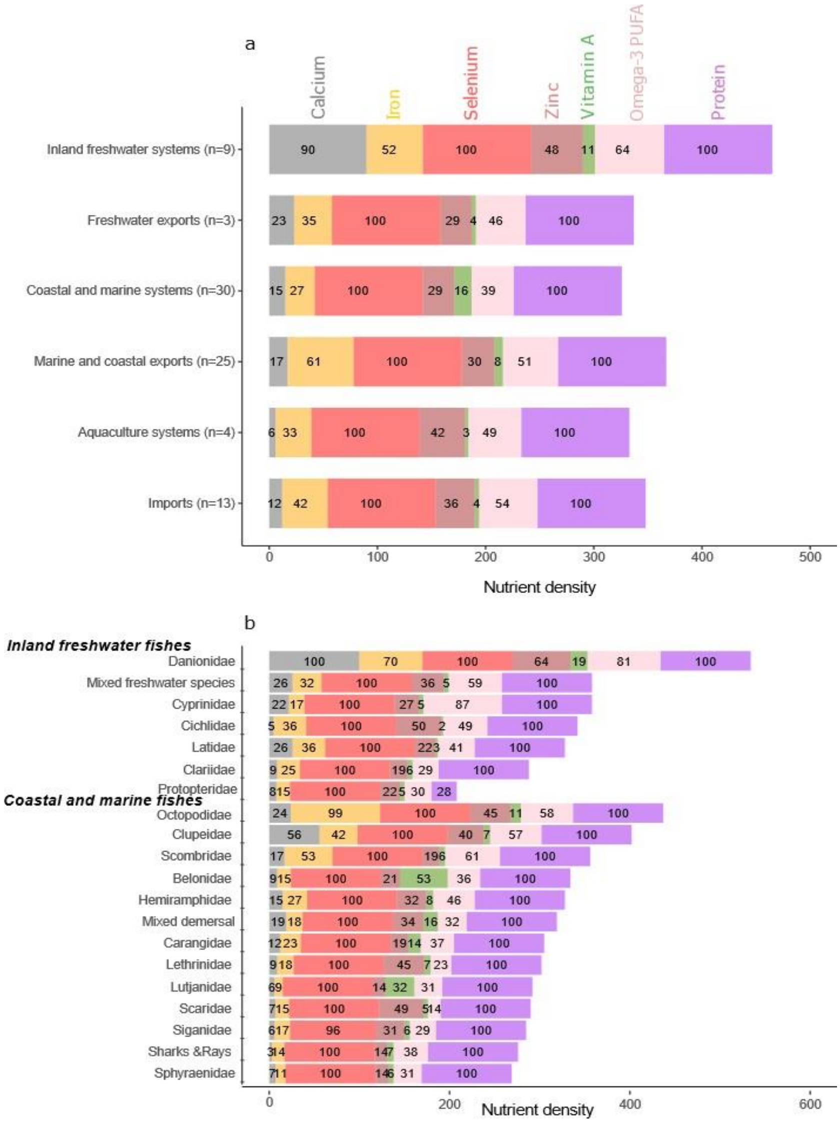


Figure 2.6 Nutrient density of fish presented as the percent contribution an average 100 g portion of fish could make towards the daily recommended nutrient intake (RNI) for a child under five years across five micronutrients (calcium, iron, selenium, vitamin A and zinc) and two macronutrients (omega-3 fatty acids and proteins) (maximum 700%) grouped by a - production source (marine capture, freshwater capture, aquaculture, imports, marine and freshwater exports (numbers in brackets refer to the number of fish taxa as reported in the data sources); b - top 20 fish taxa (making up to 95% of reported edible catch). Bars represent the contribution a 100 g portion of fish provides of 7 key nutrients relative to the recommended nutrient intake (RNI) for children under 5 years. For each nutrient, the value within the bar represents the percentage contribution to RNI. The top 7 species are from inland freshwater systems and the bottom 13 from coastal and marine systems (sorted by their quantities from most to least within the two systems)

2.4.4 Portion sizes required to meet nutrient needs

Based on the fish available in Kenya, consuming portions that range in size between 46 - 125 g, would be sufficient to meet an average of 33% of the daily nutrient needs across six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 PUFA) for a child under five years (Fig. 2.7a, b). For the most abundant fish taxa by biomass, consuming a portion of 80-90 g would be sufficient to meet these needs, the next most abundant taxa (*R. argentea* – family Danionidae) would only require a 40-50 g portion size (Fig. 2.7b). Despite the range of taxa and sources that comprise Kenya's aquatic food system, which is dominated by coastal and marine taxa, freshwater fishes constitute the largest biomass in the 40-50 g, 70-80 g, 80-90 g, and 100-110 g portion size categories. The freshwater cyprinid was the only species in the 40-50 g portion size, mixed other freshwater species constituted 46% of the 70-80 g portion size, and families Latidae – Nile perch (one species - *Lates niloticus* and Cichlidae - Tilapias (mainly *Oreochromis niloticus*) made up 50% and 36% respectively of the 80-90 g portion size, and Clariidae - Catfish (main species - *Clarias gariepinus*) was the most abundant in the 100 -110 g portion size categories where it made up 57% of the biomass (Fig 2.7b). On average, a child under 5 years old would need to consume approximately 66 g, 80 g, 89 g, or 93 g of fish sourced from inland freshwater systems, import, aquaculture systems, or coastal and marine systems respectively to meet the 33% RNI across the six nutrients (calcium, iron, selenium, vitamin A, zinc, and total omega-3 PUFA) (Table 2.6 in Appendix 1). The portion size required to reach an average of 33.3% RNI across the 84 fish taxa is presented in the supplementary figure (Fig. S2.1 in Appendix 1).

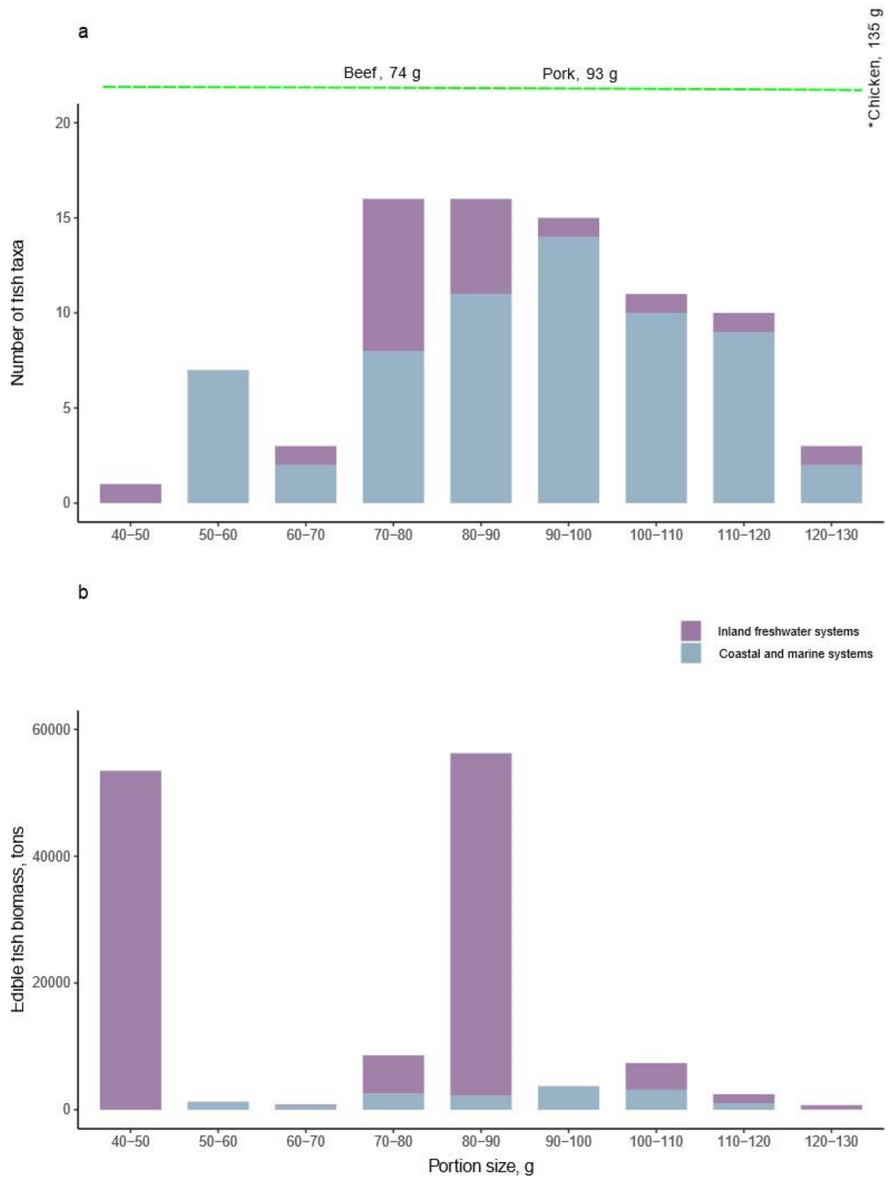


Figure 2.7 a- The fish portion size (g) required to reach an average of 33.3% of daily recommended nutrient intakes across six nutrients (calcium, iron, selenium, vitamin A, zinc, and total omega-3 PUFA) for all 84 fish taxa (2005-2020); the equivalent values for terrestrial animal source foods (beef, pork, and chicken) shown above were from Tacon and Metian, 2013. Recommended intakes are for children under 5 years old. All fish taxa were assigned to either freshwater or coastal and marine ecosystem (including aquaculture and imports). Chicken is highlighted* since it falls beyond the range of 40-130 g but forms part of dietary animal protein for most Kenyans. b - Edible fish biomass supply across the portion sizes, indicating that most of the available biomass falls between 80-90 g and 40-50 g portion size respectively

2.4.5 Potential and changes in fish contributions to nutritional security

There was a small (11%) increase in fish supply between 2005 and 2020 (Fig. 2.8a). However, over the same period, the potential of this fish supply to meet per capita fish consumption decreased by 24% and nutrient supply declined by between 25-40% (Fig. 2.8a). The largest decline in nutrient supply was for calcium while the smallest was for vitamin A (Fig. 2.8a). Despite these declines, in 2020, calcium, selenium, and protein supplies had the potential to meet the nutrient requirements (based on the assumption that 33% of each nutrient requirement comes from fish) for all children under 5 years (Fig. 2.8b). Supplies of omega-3 PUFA, iron, zinc, and vitamin A had the potential to meet the nutrient requirements for 93%, 72%, 70% and 17% of the children under 5 years, respectively (Fig. 2.8b). The current fish supply of 135,745 tons has the potential to provide fish for 13,052,432 Kenyans (24% of the national population) (based on the World Health Organization (WHO) recommendations of 2 servings (200 g) of fish per week. If targeted for local consumption by households living within 20 km of the inland and marine fishery waters, this supply would meet the recommended per capita consumption of 10.4 kg/yr for all the population (10,979,600) residing here.

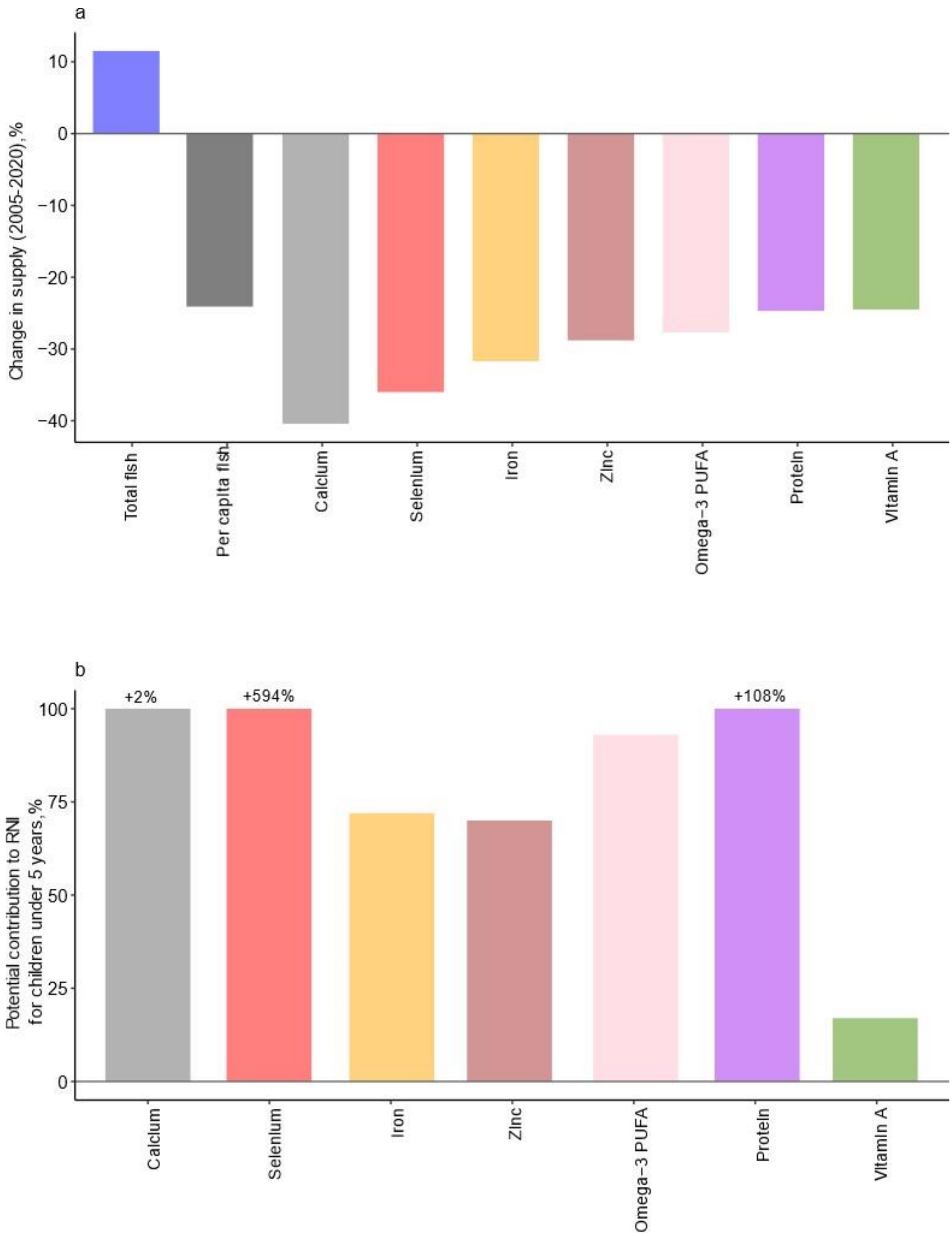


Figure 2.8 a - Change in fish supply, apparent per capita fish consumption, and nutrient supply between 2005 and 2020, and b - the proportion of Kenya's children under 5 years old whose recommended nutrient intakes (33% of requirements per nutrient) could be met with current (2020) supply from fish. Bars with positive values shown indicate those nutrients that are in surplus by the indicated value

2.5 Discussion

The findings in this chapter demonstrate that while fish supply in Kenya has increased by 11%, per capita fish consumption has declined by 24% and the total nutrient supply has decreased by 25-40%, due to both changes in the quantity and types of fish species produced and an increase in the national population. Here, I discuss the implication of this for food and nutrition security in Kenya and highlight the potential that current supply has if it were to be targeted to meet nutrient needs of vulnerable children under five years. I further evaluate two reference populations (percent of national population and populations near fishery water bodies) to show the potential of current fish supplies to meet recommended per capita fish consumption of 10.4 kg/yr.

2.5.1 Declines in fish supply for consumption threaten food and nutrition security in Kenya

Kenya experienced a 25-40% decline in nutrient supply from fish, an even greater decline than in per capita fish supply, despite the 11% increase in overall fish supply. The decline in nutrient supply is associated with changes in the composition and quantity of fish taxa, resulting from declines in freshwater taxa and increases in aquaculture, imported, and coastal and marine taxa (Fig. 2.2a). Similar declines in nutrient supply from fish have been shown in Bangladesh and Brazil, when aquaculture or imported taxa replace traditional wild species (Bogard *et al.*, 2017; Heilpern *et al.*, 2023). The changes in the quantity and types of species produced could be attributed to various factors. These include declining fish stocks in both marine and freshwater systems (Aura *et al.*, 2020; Hicks and McClanahan, 2012; Kimani *et al.*, 2018; Schubert *et al.*, 2021), and alien species invasion, rising eutrophication, and climate change impacts in Lake Victoria (Nyamweya *et al.*, 2022). There have also been large negative impacts on local fish supply due to an interplay of direct and indirect impacts of fish trade arising from higher demand for fish of Lake Victoria, mainly Nile perch (*Lates niloticus*) and the small pelagic cyprinid (*Rastrineobola argentea*), in the export market and for fishmeal respectively (Abila, 2005). The decline of nutrients could be attributed to declines of the highly nutritious freshwater silver cyprinid, *R. argentea* (family Danionidae) from Lake Victoria (Aura *et al.*, 2020). The biomass dominance of the fish supply by freshwater species is a key feature of the Kenya fishery (Schubert *et al.*, 2021). Therefore the decline in this biomass highlights the need for improved fisheries management to rebuild fish stocks, focus on nutrient-rich aquaculture and imports and harnessing nutritious small and medium pelagic coastal and marine fish that are locally important in order to increase fish supply (Njiru *et al.*, 2021). Promoting sustainable on-farm aquaculture aligns with the global trend in fish supplies that is transitioning from dependence on wild fisheries to aquaculture (Belton and Thilsted, 2014). However, such aquaculture interventions need to move from maximizing production and embrace a nutrition-sensitive approach that considers nutritional quality (Bogard *et al.*, 2017; Heilpern *et al.*, 2023). Although there have been expectations that fish imports and aquaculture growth would narrow the fish supply gaps in East Africa (Obiero *et al.*, 2019), these findings highlight the fact that there will need to be large increases in supply from these other sources, to match the increase in population (and thus, increase in demand). The supply of nutrients from these sources also must be addressed as the change in the supply will lead to a drop in the supply of essential micronutrients (Bogard *et al.*, 2017).

Between 2005 and 2020, Kenya's population grew by 46%, from an estimated 37 million to 54 million people, exceeding the 11% rate of increase in fish supply, and resulting in a 24% decline in the per capita fish available for consumption. This decline in fish consumption in Kenya is set in the context of a longer-term decline in consumption across Sub-Saharan Africa of 14% between 1990-2002, reaching a low of 6.7 kg/yr, with Sub-Saharan Africa being the only part of the developing world where fish supply per person was declining while production was seemingly increasing (Béné *et al.*, 2010). Human populations are expected to grow further across the wider East Africa and western Indian Ocean region, suggesting an increased demand for seafood at this larger regional scale (Nyamweya *et al.*, 2022; Taylor *et al.*, 2019).

2.5.2 Kenya's aquatic food systems hold potential to support nutrition security

Improving the contribution of small-scale fisheries to overall national food and nutrition demand is Kenya's Vision 2030 long-term development blueprint aspiration. However, with the characteristic fish deficits reported here and elsewhere (Obiero et al., 2019; Odoli et al., 2019; Schubert et al., 2021; Taylor et al., 2019), targeting vulnerable groups like children under five years is important. I established that fish nutrient supplies in Kenya are sufficient to meet one-third of the calcium, selenium, and protein requirements for all children under 5 years and one-third of the omega-3 PUFA, iron, and zinc requirements for over 70% of these children highlighting the potential for targeted nutrition policies to increase the consumption of fish among children. However, food systems are complex and multi-sectoral, interventions will thus need to involve multiple actors, including educationists, health and nutrition specialists, fisheries scientists, governance and policy actors (Codjia *et al.*, 2024; Kamau-Mbuthia *et al.*, 2023; Yazdanpanah *et al.*, 2023).

Children under five years are in an important life stage, during which adequate nutrition can support longer-term health benefits. Therefore, by reducing the likelihood of undernutrition, stunting, micronutrient deficiencies, and children not reaching their developmental potential (Black *et al.*, 2020; Byrd *et al.*, 2021a; Shrestha *et al.*, 2022), aquatic food systems can offer an eminent ecosystem service to be anchored in food nutrition policy and guidelines (Bennett *et al.*, 2021a). Although it is unrealistic to expect all fish to be consumed by children under five years, a range of strategies are available to include or increase fish in the diets of children. Strategies could include: incorporating fish into complementary feeding (Codjia *et al.*, 2024; World Health Organization, 2023); promoting the inclusion of fish into school feeding programs (Ahern *et al.*, 2021; Khan *et al.*, 2021); raising awareness of locally available and affordable nutritious fish (Kimiywe *et al.*, 2024; Ryckman *et al.*, 2022); sharing knowledge on fish processing strategies (e.g. converting fish into powders or pastes) to enhance uptake of fish in preferred forms by children (Kimiywe *et al.*, 2024); and revision of dietary guidelines or nutrition action plans to target this age group through recommendations that they are prioritized in the household for fish consumption (Khan *et al.*, 2021). However, achievement of target interventions would require further stakeholder engagement and strategically working together for successful implementation to improve nutrition status (Codjia *et al.*, 2024; Kamau-Mbuthia *et al.*, 2023).

There are a large number and diversity of fish taxa available for consumption in Kenya, and all are an important source of nutrition. The portion sizes for fish (46 - 125 g) needed to meet one-third of the nutrient needs of a child under 5 years are in the same range, or smaller, as other animal-sourced foods such as beef (74 g), pork (93 g) and chicken (135 g) (Tacon and Metian, 2013). Fish has the additional benefit of having many options (many fish taxa) to choose from, and locally being often cheaper (Robinson *et al.*, 2022c; Ryckman *et al.*, 2021). This diversity increases the likelihood of species being more affordable and accessible within local contexts (Ryckman *et al.*, 2021). Furthermore, fish have unique richness in nutrients that are mostly lacking in diets (Bernstein *et al.*, 2019; White *et al.*, 2021) that makes them standout as significant nutritious food for human health improvement in tropical developing nations. Certain species, such as the small freshwater cyprinid, *Rastrineobola argentea* (family Danionidae, locally called "*omena*" or "*dagaa*") have particularly high nutrient density (Byrd *et al.*, 2021a; Isaacs, 2016; Wessels *et al.*, 2023). Omena is both the most nutritious and most abundant species in Kenya; a 46 g portion is sufficient to meet one third of the dietary needs of a child under five years across 6 key nutrients. Omena is also one of the most affordable sources of fish and remains a good source of nutrition when dried (Robinson *et al.*, 2022c; Ryckman *et al.*, 2021; White *et al.*, 2021). Shellfishes (bivalve molluscs, octopus, squids, crustaceans), small marine species such as the family Clupeidae (mainly sardines) and Engraulidae (anchovies) were also found to be nutritious (Bernstein et al., 2019; Isaacs, 2016; Robinson et al., 2022). Small freshwater cyprinids, sardines, and anchovies reported here are rich in calcium, zinc, and omega-3 PUFA (Robinson *et al.*, 2022c; Wessels *et al.*, 2023). It is important to note that small portion sizes needed for the most nutritious fish are particularly valuable for targeting small children who have small stomachs, so as not to displace breast milk intake (Byrd *et al.*, 2021a; Dewey and Brown, 2003). Fish consumption in general in Kenya could be highlighted for its importance to human health according to nutrient content profiles, and particularly nutrient needs for vulnerable stages such as when pregnant, lactating, or under the age of five years (Bonham *et al.*, 2009; Byrd *et al.*, 2021a; Cartmill *et al.*, 2022; Gibson *et al.*, 2020).

The portion size ranges found here call for a reconsideration of the dietary guidelines in Kenya. The Kenya National Guidelines for Healthy Diets and Physical Activity 2017 recommend at least 2 servings/week of lean meat including fish, with each serving of fish approximated at 30 g (Ministry of Health, 2017). This translates to a minimum of 60 g/week. Our findings suggest that consuming the most nutritious and abundant fish (*R. argentea*, family Danionidae) would require consuming 46 g/day while consuming the less nutritious family Gempylidae (snake mackerels) would require consuming 125 g/day (Supplementary Fig. S2.1 in Appendix 1) to meet recommended nutrient intakes across the six valuable micronutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 PUFA) for a child under five years. Hence to help tackle malnutrition among target population groups such as children below five years, whose nutrient needs I used in this study, there would be a need to have taxa-specific guidelines such as 46 g/day for the nutritious freshwater cyprinid (family Danionidae) and a minimum average of 80 g/day for the more abundant fish taxa that includes Nile perch (family Latidae) and tilapias (family Cichlidae). Such taxa-specific guidelines exist in the United States whereby the United States Environmental Protection Agency (EPA) provides advice on fish consumption based on mercury levels in different fish species and has a searchable database that allows users to find specific information about the recommended consumption amounts for different types of fish caught in various bodies of water across the country (https://www.epa.gov/), and Australia and New Zealand where the governments of Australia and New Zealand jointly publish fish consumption guidelines that provide advice on the recommended frequency of consumption for different fish species (https://www.foodstandards.gov.au/). The proposed ranges of daily portions in Kenya match recommendations by many nations and global bodies on how much fish a population must eat to have beneficial health outcomes that have been found to vary widely from 97 - 550 g/week (Thurstan and Roberts, 2014). The findings highlight a range from 92 to 160 g/week if the twice-per-week consumption recommendation is maintained or maximized at 322 to 560 g/week assuming daily fish consumption. However, in Kenya, achieving daily consumption of fish would be challenging due to the declining per capita fish supply and declining nutrient density. Therefore, the potential of fish supply and nutrients to support nutritional security would require a targeting strategy, such as identifying populations with specific nutrient needs or those near fishery water bodies while considering the interplay of factors that may influence fish consumption.

Kenya's per capita consumption estimated here at 2.5 kg/capita/yr would need to increase four-fold to meet common global (10.2 kg/capita/yr) (Willett *et al.*, 2019) or regional (10.6 kg/capita/yr) (Canty and Deichmann, 2022) recommendations for fish consumption, and is one-eighth of the global average fish consumption of 20.3 kg/capita/yr (FAO, 2020). The present fish supply can meet the national per capita fish consumption of 10.4 kg/yr for 24% (13,052,432 people) of Kenya's population. Alternatively, this supply was found adequate to meet the per capita fish consumption of all Kenya's population (11 million people) residing 20 km from inland and marine fishery water bodies. However, there is a need to seek a variety of interventions including improvements in fisheries management, if the fishery is to be enhanced to contribute to increased fulfillment of recommended nutrient intakes and food and nutrition security commitments of the nation. Thus, ensuring Kenya's fish food system can support food and nutrition security will require policies and implementation frameworks that identify where interventions are needed for the vulnerable, lactating mothers, and children, considering inadequate nutrient intakes in children can result in poor health, educational, and economic outcomes (Byrd *et al.*, 2021a; Ryckman *et al.*, 2021; Shrestha *et al.*, 2022). Further, mainstreaming of the information on nutrient contribution from fish in food policies would be a positive human developmental milestone, especially in areas with reported cases of undernutrition including those close to small-scale fisheries resources. Therefore, maintaining the supply and accessibility of fish from the different sources and fish taxa would be critical towards supporting dietary quality. However, due to supply inadequacy, further assessment to identify 'problem nutrients' and identify those in need of nutrition is advised. This could be guided by the understanding that not all communities in Kenya consume fish due to various socio-cultural, economic, and geographic reasons (Ayuya *et al.*, 2021). This calls for concerted efforts on the inclusion of these small-scale fisheries (the usually forgotten food) in food and nutrition security policies and dialogues for the country to achieve milestones in the pledges to the sustainable development goals and other food-related agenda.

2.6 Conclusions

By combining fish nutrient content information with supply, this study unveiled the nutrient supply of Kenya's fish, teasing out how this often-forgotten food can be harnessed to alleviate nutrient deficiencies in vulnerable target population groups such as children under five years, or populations close to fishery water bodies. In doing so, I firstly, established that the fish taxa supplied in Kenya can play a substantial role in ameliorating micronutrient deficiencies among target vulnerable populations. Marine and inland freshwater capture fisheries, aquaculture, and imported supplies contain key nutrients that would be beneficial to improved health. I highlight that fish consumption could be beneficial to target vulnerable populations such as children under five years, based on the nutrient profiles of the available fishes from the four main sources. With this information, national food policy and dietary recommendations could be updated. For example, diets incorporating fish within the portion sizes of 46 g per day could be used in public health nutrition policies to advise on the prevention of micronutrient deficiencies in children under five years, based on consumption of the abundant fish family Danionidae (*Rastrineobola argentea*), commonly referred to as *omena* or *dagaa* in local contexts. Similar guidelines can be followed for other fish taxa highlighted in Table 2.6 and supplementary fig. S2.1 in Appendix 1 of this thesis, but being cognizant of available fish quantities, diverse fish preferences, quantities of fish that a child can consume, acceptability, cultural contexts, and affordability of the fish.

Secondly, I identified three pathways by which the fish supplies can help improve food and nutrition security by being mainstreamed into national food and nutrition policy:

1. Promoting the intake of nutrients from across diverse fish taxa. This would be dependent on which nutrient types are locally deficient. Advising on the options available based on the results of this study would be limited to the seven nutrients that were assessed.
2. Adopting proposed portion sizes of fish taxa that an individual would need to consume to meet 33% of nutritional requirements across the six key nutrients.

3. Supporting scalability of our assessment of potential contribution of fish to tackling malnutrition in children under five years to other vulnerable population groups such as pregnant women, lactating women or any other. However, this pathway would require increased fish supply to reverse the declining per capita fish supply for nutrition security.

Thirdly, I highlight that declining inland freshwater fish supply in terms of quantity may be compensated for by increases in marine and coastal fisheries production, aquaculture production, and imports. However, because on average, these sources are less nutritious than freshwater sources, and human population is expected to continue to grow, greater increases than losses will be necessary. The nutritional quality of fish lost by the decline of nutritious freshwater species would not be compensated for by these three sources, highlighting the need to ensure conservation and management efforts are put in place to sustain inland freshwater fisheries, specifically of the Lake Victoria's *R. argentea* (Family Danionidae) that are taxa with the highest nutrient density.

Finally, through this study, I make an important contribution to the body of empirical evidence showing that the inclusion of tropical small-scale fish food systems in food policy could support efforts to tackle nutrient deficiencies by supplying key bioavailable nutrients including calcium, iron, selenium, vitamin A, zinc, total omega-3 PUFA, and protein. Although our grouping of fish at broad taxa reported in fisheries statistical bulletins could obscure some nutritious species, these findings offer an improvement from what is reported in the current Kenya food tables and is aligned with how fisheries resources are assessed and sold. For future improvements, I propose that further research be focused on disaggregating fish supplies at the species level as data collectors get trained in fish taxonomy. The need to mainstream small-scale fisheries in food system policies, and dialogues would therefore be key to meeting national and international commitments to tackling all forms of hunger. I suggest some caution in the interpretation of the nutrient contribution from aquaculture in this study since it was based on nutrient content estimated for fish taxa in the wild, but aquaculture species may have varied nutrient concentrations, hence a gap for future investigations.

Chapter 3. Fish markets facilitate nutrition security in coastal Kenya: empirical evidence for policy leveraging

3.1 Abstract

Fish markets are key to supporting the availability and accessibility of nutritious food but are often overlooked in food and nutrition research and policy. Yet, most of the fish that is available and important for nutrition (Chapter 2), can only be made available and accessible to consumers through trade. Therefore, in this chapter, I investigated fish markets in coastal Kenya, using data from 223 semi-structured interviews collected through market surveys, and analyzed their potential to meet recommendations for consumption and alleviate malnutrition in a vulnerable coastal population (children under five years). The results show that women small-scale traders dealt in lower quantities of fish per trader than the other traders, yet sold more nutritious fish. Fish shop traders sold enough fish to meet 129% of the recommended intake of fish (10.4 kg/capita/yr) for all people within the assessed towns, whereas women small-scale traders sold enough to meet 84% of the recommended intake. All market traders were key to making nutritious fish available, with a 100 g portion of fish providing at least 25% of required intakes, across five nutrients, and women small-scale traders providing over 25% of required intakes across six nutrients for a child under five years. The average cost of a nutritious portion of fish was KES 31 (USD 0.22), ranging from KES 12 (USD 0.08) to 49 (USD (0.34), which provide 33.3% of the required nutrients (averaged across six nutrients), with the most nutritious fish being notably cheaper. Findings from this chapter contribute key empirical information to fill the knowledge gap on the role of subnational fish trade in supporting nutrition. I recommend the incorporation of this information to support transformative policy toward promoting nutrition-sensitive fish markets in Kenya.

Published - Omukoto JO, Graham NAJ, Hicks CC. (2024). Fish markets facilitate nutrition security in coastal Kenya: empirical evidence for policy leveraging. Marine Policy 164 (2024). https://doi.org/10.1016/j.marpol.2024.106179

3.2 Introduction

Availability and accessibility of diverse, nutritious, and safe fish for food and nutrition security are key to reducing malnutrition, especially among vulnerable populations adjacent to fishery resources (de Bruyn *et al.*, 2021; FAO, IFAD, UNICEF, WFP and WHO, 2020; Gephart *et al.*, 2021; Hicks *et al.*, 2019, 2021; HLPE, 2020; Maire *et al.*, 2021; Obiero *et al.*, 2019; Simmance *et al.*, 2022). However, current food policy tends to focus on the availability of food, overlooking an evaluation of what the right food is and whether people can access it (Allen and de Brauw, 2018). Large-scale studies have shown that fish is often one of the most affordable sources of nutritious food (Robinson *et al.*, 2022c; Ryckman *et al.*, 2022), highlighting the potential for fish to meet the needs of those who need them most (Allegretti and Hicks, 2022). However, studies seldom examine the role of local fish markets in supporting nutritional security or evaluate the nutritional contributions they can make, creating a gap in the evidence needed to inform nutrition-sensitive food policies.

Fish markets are diverse, can be formal or informal, supply a range of products, target different consumers, and be controlled by a range of actors (Moreau and Garaway, 2021; Fonner and Sylvia, 2015; Mirera *et al.*, 2023). Markets can affect the availability and accessibility of food and nutrition security, and are thus key to sustainable development goal number 2: attaining zero hunger by 2030 (FAO, IFAD, UNICEF, WFP and WHO, 2022). Market availability of fish refers to the presence of sufficient quantities and qualities of fish to satisfy the dietary needs of consumers, being free from adverse substances and acceptable within existing culture (Clapp *et al.*, 2021; HLPE, 2020). This implies that there should be enough fish available on the market that is preferred for local consumption and sourced from available production channels (Hasselberg *et al.*, 2020). In coastal Kenya, consumers obtain fish from one or more of the available distribution networks, including local small-scale fishers at the landing sites, local fish markets, fish shops, supermarkets, and international imports/trade (Wamukota and McClanahan, 2017; Matsue *et al.*, 2014; McClanahan and Abunge, 2017; Mirera *et al.*, 2023). Access relates to an individual's or household's economic, social and physical means to acquire fish for an adequate dietary intake at a level to ensure that satisfaction of other basic needs is not threatened or compromised;

and that adequate fish is accessible to everyone, including vulnerable individuals and groups (Clapp *et al.*, 2021; HLPE, 2020). Therefore, fish markets need to supply enough, affordable, and nutritious food to support the availability and access dimensions of food and nutrition security.

Several studies across East Africa have examined the availability and accessibility of fish through the lens of markets, focusing on local consumption (Bundala *et al.*, 2020), physical and economic access (de Bruyn *et al.*, 2021), affordability and availability of preferred fish (Hotz *et al.*, 2015; Thakwalakwa *et al.*, 2020). Other studies examine the influence of perceptions, capital assets, market, and power dynamics on who is able to participate in markets, the volumes and species traded, and on value chain development and economic returns (Kimani *et al.*, 2020a, 2020b, 2020c; Matsue *et al.*, 2014; Wamukota, 2009). Although, local fish trade is recognized as important for nutritional outcomes (Bundala *et al.*, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2021; Githukia *et al.*, 2014; HLPE, 2014; Hotz *et al.*, 2015; Ibengwe *et al.*, 2022; Thompson and Amoroso, 2014), these studies tend not to examine the nutrient content of traded fishes, nor evaluate the differentiated role of market actors in tackling malnutrition.

Here, I evaluated the role of local fish markets in making sufficient quantities of nutritious fish available and affordable, and in doing so, determined the potential contribution of the market traders in providing meaningful nutrients to vulnerable populations. The objectives of the research were to: 1. Characterise the different market traders operating in coastal Kenya; 2. Establish the nutrition quality of fish sold by the different market traders; 3. Evaluate the cost of nutritious fish sold by different market traders; and 4. Determine whether traded fish has the potential to meet the fish consumption and nutrient needs of children under five in the adjacent populations.

3.3 Materials and methods

3.3.1 Study sites

Kenya's coastal region consists of six devolved counties: Mombasa, Kwale, Kilifi, Tana River, Lamu and Taita Taveta. Kilifi and Kwale are the most active fishing counties in the region; Kilifi represents 35% of the fishery landing sites, while Kwale represents 25% based on the Kenya Marine Fisheries Frame Survey Report of 2016. The two counties accounted for 68% of the 35,596 metric tons of fish landed during 2022 (Kwale – 42% and Kilifi – 26%) based on the Fisheries Statistical bulletin report, issue 2023. Market survey data was gathered from two towns in Kilifi (Malindi and Mtwapa) and one town in Kwale (Ukunda) (Fig. 3.1). These towns were purposively selected based on their characteristic mix of urban and rural households, diversity in fish demands and purchasing abilities due to the cosmopolitan nature of the resident populations, high population density, and closeness to productive marine fish landing sites. The human population across these three towns, based on the 2019 national census survey, was 289,884 people. Malindi was the largest town with a population of 166,357 (57.4%) followed by Mtwapa, with a population of 70,990 (24.5%) and Ukunda, with a population of 52,537 (18.1%). Fish forms an important part of the diet for most of the residents within the three towns and the small-scale fisheries support many of the adjacent rural communities in terms of food and nutrition, income, and employment (Daw *et al.*, 2023; Hicks and Cinner, 2014; Njiru *et al.*, 2021).

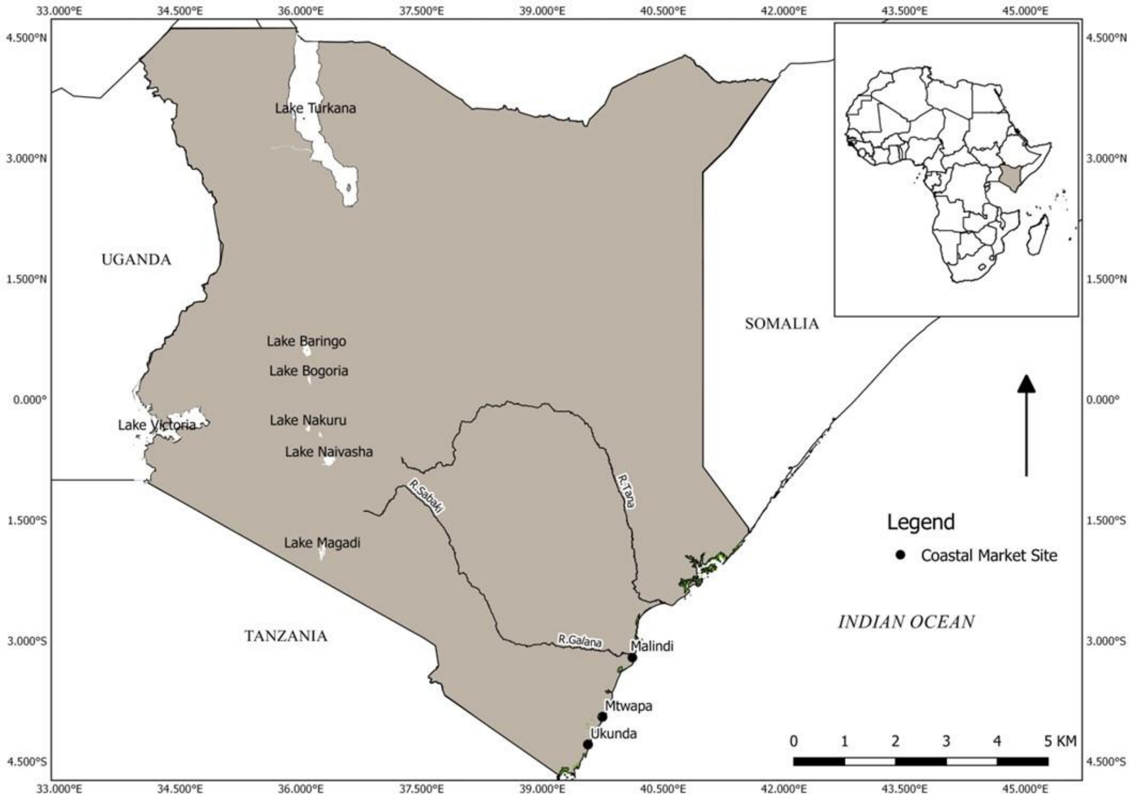


Figure 3.1 Map of Kenya showing the three coastal town market sites (Malindi, Mtwapa and Ukunda) where the fish market surveys were conducted

3.3.2 Fish market surveys

Before starting the market surveys, fisheries officers within the jurisdictions of the three towns and the associated fish landing co-management units (also known as beach management units) were briefed on the objective of the surveys through preliminary meetings at their offices. They were asked if there was existing data on the gaps that the survey planned to fill. At all three towns, there was no relevant data except for Mtwapa that had some basic information on existing traders, albeit not aligned to the objective of the survey. Consequently, the survey was conducted to collect novel data on fish trade by market traders during February and March 2021 by the lead author and four trained research assistants.

Three fish market surveys (10 days per survey) were conducted between 13th February and 13th March 2021 in Malindi, Mtwapa, and Ukunda. A total of 223 respondents, categorized as women small-scale traders (n = 109), men small-scale traders (n = 46), fish shop traders (n = 59), and middlemen/dealers (n = 9) (Table 3.1) were interviewed to identify key traded fish taxa, quantities, and prices per unit quantity. Although I sought to gain proportional representation of the different market traders, this was only possible for the women small-scale traders (approximately 50% were interviewed), men small-scale traders (covered ~ 60%) and fish shop traders (covered ~ 70%) but not for the middlemen/dealers' category because in some cases, traders who fell into the middlemen/dealer category preferred to be considered as fish shop traders. However, I retained the middlemen/dealer category since there were still some respondents who solely identified as middlemen/dealers within the sampling frame and assumed a coverage of 70%.

Table 3.1 Summary of the number of traders interviewed in the three towns and the respective market types they represented during this study

Market traders \ Towns	Malindi	Mtwapa	Ukunda	Total
Women small-scale traders	26	56	27	109
Men small-scale traders	10	12	24	46
Fish shop traders	34	9	16	59
Middlemen/Dealers	5	3	1	9
Total	75	80	68	223

The fish market survey was done using mixed purposeful sampling, stratified random sampling, and opportunistic sampling designs (Palinkas *et al.*, 2015) to be able to capture all required data amidst unpredictable trade operation times associated with COVID-19 time restrictions and erratic fish supplies. Purposive sampling was used to get information from the four categories of market traders while stratified random sampling allowed for subsampling within the women small-scale traders. Opportunistic sampling was used for fish shop traders within the towns. The market survey employed a pre-tested structured questionnaire that was administered through one-on-one interviews with the traders, upon being granted permission to be interviewed. Each interview took between 15 and 45 minutes depending on the nature of trade and whether there were interruptions from respondents due to calls to attend to business. The data obtained included free listing the ten most traded fish taxa, sources of fish, type of market category the respondent identified with, gender of the trader, market location, unit buying price and unit selling price, estimated average quantities traded per day, and number of days traded per month.

3.3.3 Description of the fish market traders

The women small-scale traders are fish mongers, also referred to locally as '*mama karangas'*, who deal in diverse fish taxa, mainly processed forms of deep fried or sundried fish, although some fish are also sold fresh or frozen to selected consumers (Matsue *et al.*, 2014; Wamukota, 2009). Women small-scale traders have been thought to deal in small, cheap fish and restricted to local markets (Matsue *et al.*, 2014; McClanahan and Abunge, 2017). However, during the market surveys, I found that the women small-scale traders also dealt in large narrow-bodied fishes, such as barracudas, needlefishes, and halfbeaks and would slice them into small pieces before frying and selling. The women small-scale traders generally sold fish in smaller quantities, at price per: piece of fish, portion of fish, pile of several small fishes, or based on measuring containers of different sizes filled with smaller fishes; targeting low income consumers. They seldom weighed their fish for sale using the standard weight of kilograms (kg). Thus, their responses to price per kg was based on their expert estimation of how many pieces or what measure they associated with a kg of fish.

The men small-scale traders deal in similarly diverse taxa as the women small-scale traders but mainly offer mixed small to larger sized fresh or frozen fish for sale, and a small number deal in large amounts of dry fish. The men small-scale traders sell fish along roads, in open air markets and in temporary sheds. Their target consumers include lower middle-class buyers who prefer to buy fresh fish for home use and local small-scale eateries or hotels. Some of these men small-scale traders offer partial fish processing for their consumers in the form of descaling, gutting, and slicing.

Fish shop traders handle fish within formal settings of a shop installed with cold storage freezers, weighing balance, and potable tap water. They also act as middlemen/suppliers of fish to the small-scale traders who buy imported frozen mackerels and an assortment of other coastal and marine species for further processing and trade or sale in the same product form. At some landing sites, the fish shop traders owned boats and fishing gears and employed the fishing crew who land and bring the fish catch to the shop. These were clearly observed in

Malindi and Mtwapa towns, while it was not observed in Ukunda during the time of the market survey.

Middlemen or dealers refer to traders who act as direct intermediaries between fishermen and an assortment of other fish buyers (the preceding 3 types of traders, export processors, and direct consumers). These middlemen/dealers were mainly traders with freezers at the landing sites. They may or may not be owners of boats and fishing gears at the landing sites, but they do facilitate the trade of high-value fishes that include shellfishes (lobsters, prawns, octopus, and squids) and large fishes for factory processing, or hotel contracts. Some also traded in mixed finfish species, which they bought from fishers and sold to small-scale traders or direct consumers who preferred buying fish at the landing sites.

3.3.4 Estimating traded edible fish quantities

Information about traded fish quantities was provided by the respondents as estimated daily traded amounts in kilograms. These weights were first converted into daily traded quantities in tons. Next, the daily traded quantities in tons were multiplied by 365 (number of days in a year), then by a factor of number of days traded per month divided by average number of days per month (30 days) to correct for number of days when trading was not carried out. The derived annual quantities were then scaled up to obtain an estimate of traded fish quantities by multiplying by a factor of 2, 1.67 and 1.43 for women small-scale traders, male small-scale traders and fish shop traders/dealers respectively based on survey coverage. These conversion factors were obtained by dividing 100% by the approximate sampling coverage of the traders (50% for women small-scale traders, 60% for men small-scale traders, and 70% for both fish shop traders and dealers).

Before determining the nutrient content and supply for traded fish taxa, and where applicable, the above estimated annual traded quantities were converted from reported raw wet weight into edible weights using conversion factors of 0.87 for finfish (based on deboning and gutting), 0.38 for crustaceans and 0.17 for bivalve molluscs (Edwards *et al.*, 2019). For all other taxa (e.g., octopus and sea cucumbers) and fish that are consumed whole, or reported as processed products, conversion factors were not applied.

3.3.5 Determining nutrient content, density, and price of traded fish

For each of the 47 fish taxa traded across the four categories of traders, the nutrient content of five micronutrients (calcium, iron, selenium, vitamin A, and zinc) and two macronutrients (total omega-3 PUFA, and proteins) were determined based on modelled estimates available from FishBase (Froese and Pauly, 2021; Hicks *et al.*, 2019; MacNeil, 2021). Where data were reported to species level, species nutrient values were taken directly from FishBase. Where fish type was reported at broader fish taxa level, I used the average nutrient values across species in that fish type grouping that were specific to Kenya's geographical region on FishBase.

The nutrient density of each fish taxa was calculated based on the nutrient content of the fish taxa relative to established recommended nutrient intake (RNI) values. This study used RNI values for children aged under five years as recommended by the FAO and WHO (FAO/WHO, 2004) for micronutrients, the Institute of Medicine (Institute of Medicine, 2006) for proteins' adequate intakes (AI) and for total omega-3 polyunsaturated fatty acids (PUFA) based on the FAO (FAO, 2010). Coastal counties in Kenya are characterized by high levels of child undernutrition (Cartmill *et al.*, 2022; Muraya *et al.*, 2016; Kamau-Mbuthia *et al.*, 2023), I therefore focused on under five years as a vulnerable, and target population group for malnutrition intervention in Kenya. Nutrient density was defined and calculated as the contribution a 100 g portion of fish (Drewnowski, 2009) could make towards the RNI of a target population group (for this study, children under five years) (Hicks *et al.*, 2021; Maire *et al.*, 2021). Nutrient density is therefore the sum of the percentage contribution that 100 g of raw fish makes to the recommended dietary intake across all seven nutrients (calcium, iron, selenium, vitamin A, zinc, omega-3 PUFA, and proteins) (Maire *et al.*, 2021). The percentage contribution to RNI for each nutrient was capped at 100% to prevent extreme values dominating patterns of variation in density scores for fish taxa with especially high values for some nutrients such as protein and selenium (Maire *et al.*, 2021). Nutrient density scores can therefore scale up to a maximum potential value of 700%, where all 7 nutrients are fulfilling recommended nutrient intakes. The weighted average of nutrient density across all reported fish taxa by the four market traders and across the 20 most traded fish taxa were calculated.

To determine the portion size needed to meet 33.3% of recommended nutrient intake across six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 PUFA), the amount or portion size of fish in grams that would be required to meet an average of 33.3% of the recommended nutrient intake across the six nutrients for a child under five years old (Beal, 2020; Hicks *et al.*, 2021; White *et al.*, 2021) was calculated for each of the 47 fish taxa. The contribution of each nutrient is capped at 100%, such that an average of 33.3% of requirements can be met by two nutrients providing 100% of requirement or six nutrients providing 33.3% of the requirements (Beal, 2020; White *et al.*, 2021). The cost of a portion size that could meet the 33.3% RNI across the six nutrients was then estimated by dividing the weight of this portion size by 1 kg and multiplying by the taxa-specific price of a kg of fish.

3.3.6 Determining the nutrient supply and potential to meet consumption and nutrient requirements

To determine the potential of the quantities of fish by each trader category to meet annual per capita fish consumption for the total population in Malindi, Mtwapa and Ukunda, the annual traded fish quantities were divided by the total population of people residing in the three towns. The annual per capita fish consumption was then divided with the recommended per capita consumption of 10.4 kg/yr and multiplied by 100 to obtain the percentage contribution of the traded fish to meet apparent per capita fish consumption.

The nutrient supply for each of the seven nutrients was calculated by multiplying nutrient content of fish taxa by their scaled up edible traded weights. To determine the potential of the nutrient supply by each market type to meet requirements for the population of children under five years in Malindi, Mtwapa and Ukunda, firstly, the nutrient supply for each nutrient was divided by the total population of children in the three towns to get nutrient supply per child. The nutrient supply per child was then divided by the recommended nutrient intake of that nutrient and multiplied by 100 to obtain the percentage contribution of the nutrient supply to the nutrient requirements of the child. The annual population estimate for all the people and for children under five years at the three market towns was sourced from Kenya National Census Survey Report of 2019. This age group was assumed to make up approximately 13% of the total population of the three market towns as per the national level estimate of proportion of children under five years.

3.3.7 Data analyses

To examine the differences in the average traded fish quantities and unit prices among market traders, the data was first checked for linear model assumptions of normality using visual normal Q-Q plots, distribution histograms and Shapiro-Wilk W test and homogeneity of variance using Levene's test within the free publicly available R 4.0.5 (R Core Team, 2022). Due to the lack of normality and homogeneity of variance even after logarithmic transformations of the data, the non-parametric Kruskal-Wallis rank sum tests were applied to examine the differences followed by pairwise Wilcoxon rank sum tests with continuity correction to identify main sources of the differences observed. These analyses were done at alpha 0.05.

The relative associations of the market traders and the 47 traded fish taxa were examined using principal component analysis (PCA) (Kassambara, 2017; Paliy and Shankar, 2016). The PCA was preceded by detrended correspondence analysis (DCA) to examine the length of the first axis before deciding which analysis to use (Paliy and Shankar, 2016) whereby PCA and RDA < 3 and 4 < CA and CCA criteria was used. The first axis length for the market traders was 2.3 thus the decision for applying PCA to examine key fish taxa by the quantities traded among the different market traders.

3.4 Results

The research findings are based on responses from fish traders regarding their local knowledge about the fish traded, and business transactional memories. Since the respondents did not share their daily diaries where records of activities were kept, there may be variations in quantities traded and prices indicated based on their recall aptitudes. The interpretation of the results and the discussions are therefore made with due consideration of these limitations and a reflection on the realistic validity of the information by cross-checking from fish trade and marketing studies within coastal Kenya.

3.4.1 Status of fish trade by quantities, prices, and fish taxa

Overall, it was found that the average fish quantities sold per trader across the four market traders varied significantly (Kruskal-Wallis $\chi^2 = 91.5$, df= 3, $p < 0.0001$) with a fish shop trader dealing in more fish quantities, followed by a middleman/dealer, man small-scale trader, and lastly woman small-scale trader (Table 3.2). There were a few cases (n=6) where individual traders dealt in larger volumes (over 50 tons/year), but many of the traders transacted less than 10 tons/year. The quantities of fish offered by the traders varied between 1 to 350 kg per day and on average was approximately 20 kg per day. The overall average unit (per kg) price of fish was found to vary between KES 250 – 500 (USD 1.71 – 3.42) with per unit weight price differences among the market traders not statistically significant (Kruskal-Wallis $\chi^2 = 3.12$, df= 3, $p = 0.374$).

Table 3.2 Mean annual traded fish quantity per trader for each of the four market categories in coastal Kenya and the mean price per unit weight, (KES - Kenya Shillings, USD - United States of America dollar), quantities with similar superscript letters are not statistically different across the traders

Market traders	Fish taxa sample size, n	Mean quantities traded, per trader per year, kg	sem (+/-)	Mean unit price (KES)	sem (+/-)	Mean unit price (USD)	Description of the unit of sale by the traders
Women small-scale traders	400	3711.43^{c}	242.10	356.90	4.87	2.44	Small: Mostly traded as the number of pieces, piles, cup, or tin measure depending on species. Measures approximated to kg by respondents.
Men small-scale traders	223	4522.29^{b}	358.75	384.69	16.60	2.63	Small whole to medium fish: Measured by unit weights as kg or nearest 100 g.
Fish shop traders	348	6681.75^{a}	521.51	401.93	13.61	2.75	Small, medium, and large whole fish: Measured by unit weights as kg or nearest 100 g. Too large fishes cut into portable chunks or pieces.
Middlemen/Dealers	53	4932.56^{ab}	699.34	515.28	153.16	3.53	Small, medium, and large whole fish: Measured by unit weights as kg or nearest 100 g. Too large fishes cut into portable chunks or pieces.
Kruskal-Wallis chi-square		91.5		3.12			
Kruskal-Wallis chi-square df		3		3			
Kruskal-Wallis chi-square p value		<0.000		0.3741			

*sem – standard error of the mean

Principal component analysis (PCA) of the associations among market traders and traded fish taxa revealed women small-scale traders having greatest factor loadings and contributing to variation on the first axis (29.4%) while men small-scale traders contributed significantly to both the first and second axis, and fish shop traders and middlemen/dealers contributed significantly to the variations along the second axis (27.3%) (Fig.3.2, Table 3.3). The women small-scale traders were associated with the freshwater cyprinid (family Danionidae), mullets (Mugilidae), tilapias (Cichlidae) and surgeonfishes (Acanthuridae) on the first PCA axis while fish shop traders and middlemen/dealers were associated with grunters (Terapontidae), parrotfishes (Scaridae), tripletails (Lobotidae) and Albacores, Bonitos, Kawakawas, Mackerels, Tunas, Wahoos (Scombridae) along the second axis. Three taxa, Portunidae (crabs), Ostreidae (shelled molluscs) and Holothuridae (sea cucumbers) were significant on both the axes but were not highly traded by any of the market traders because of their significantly smaller quantities.

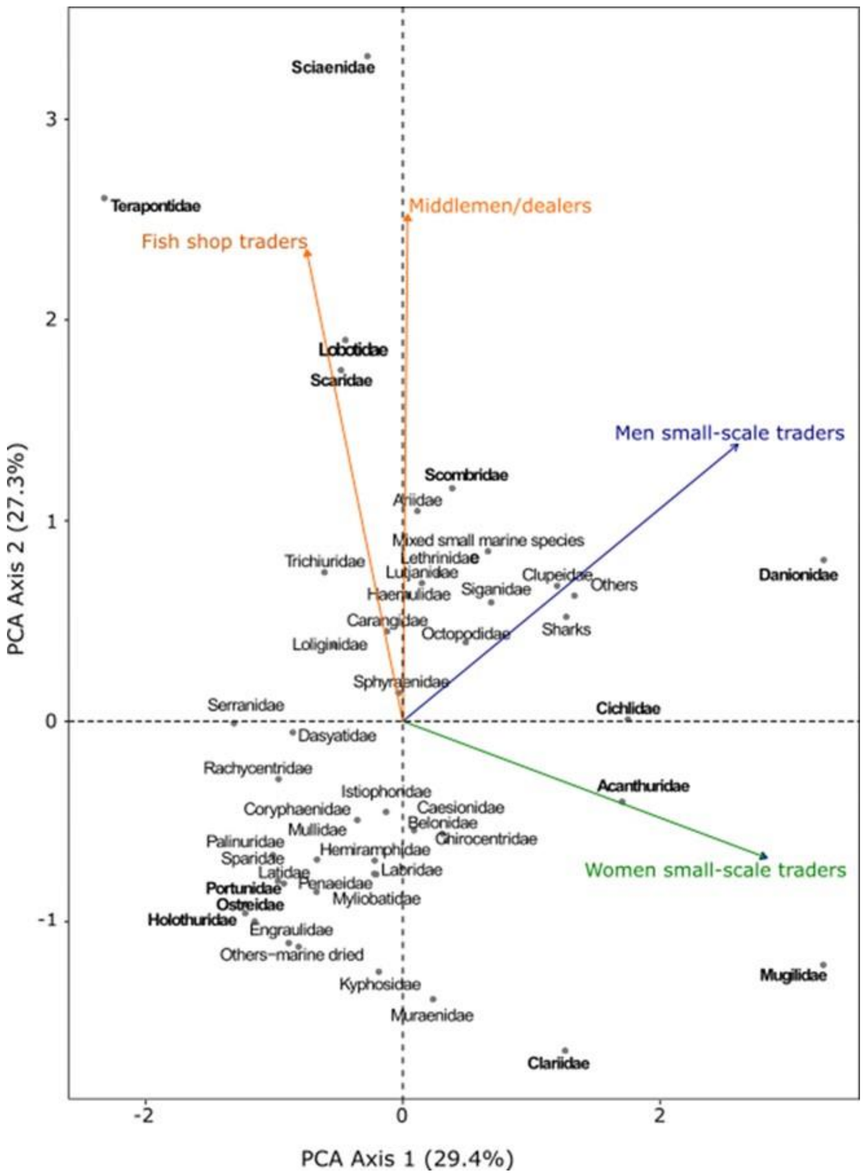


Figure 3.2 Principal Component Analysis (PCA) of the association of traded fish taxa and the four market traders based on the quantities of fish transacted, whereby women small-scale traders contributed significantly to the variation on the first axis while fish shop traders and middlemen/dealers contributed significantly to the variation on the second axis and men small-scale traders contributed significantly to both axes; fish families in bold were those contributing significantly to the variations on both axes

Table 3.3 Significant correlation coefficients of the fish market traders on the first and second PCA axes

Market actors	**Correlation coefficient**	**p-value**
a. PCA 1 (29.4%)		
Women small-scale traders	0.78	< 0.0001
Men small-scale traders	0.72	< 0.0001
b. PCA 2 (27.3%)		
Middlemen/Dealers	0.70	< 0.0001
Fish shop traders	0.65	< 0.0001
Men small-scale trader	0.38	< 0.0001

3.4.2 Nutrient content and density of the main traded fish taxa and by market actors

Women small-scale traders offered fish that were on average, more nutrient dense than other traders. The average nutrient density of a 100 g fish portion sold by women small-scale traders was 388% (Fig. 3.3a). In contrast, the average nutrient density of a 100 g fish portion sold by the other three market traders ranged from 325% to 328%. The calcium, iron, and zinc content of fishes sold by women small-scale traders was notably (over 30%) higher than that of the other three traders (Fig. 3.3a). The top 20 most traded fish taxa have sufficient quantities of protein and selenium in a 100 g portion to fully meet requirements for a child under five years. However, there were differences in the nutrient densities of fish taxa for calcium, iron, selenium, vitamin A and zinc. The freshwater silver cyprinid (Danionidae) was the most nutrient-dense for all nutrients except vitamin A, followed by mullets (Mugilidae), sardines (Clupeidae), octopus (Octopodidae) and squids (Loliginidae) (Fig. 3.3b). One noticeable feature of the nutrient density of the freshwater silver cyprinid (locally called "omena") was the high level of calcium and zinc, while the shellfishes (octopus and squids) were nutrient-dense with iron. There was evidence of some nutrient density similarities and particular variations across the 20 most traded fish taxa indicating possibilities of the traded fish species being able to complement and/or substitute each other based on the nutrient profiles.

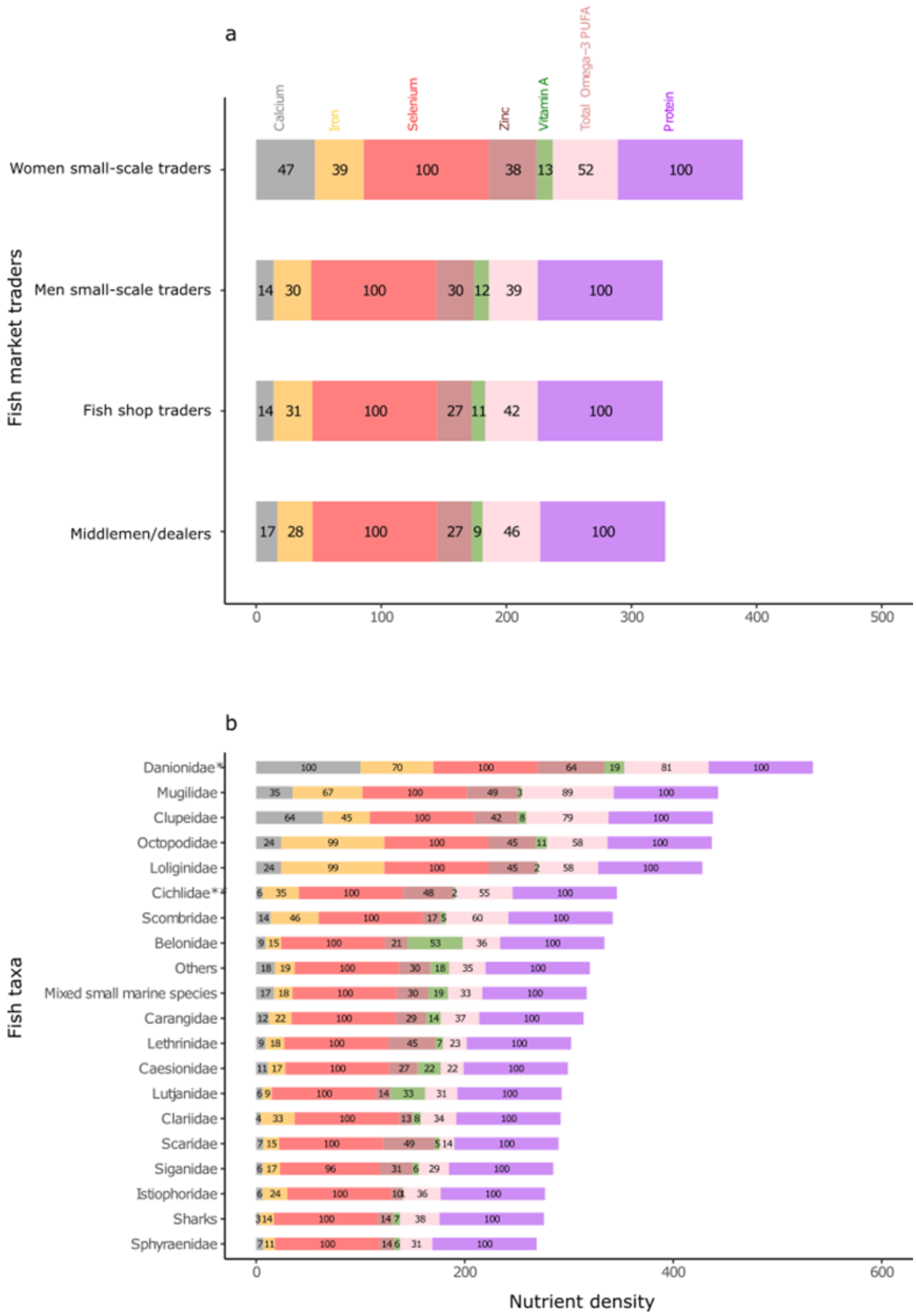


Figure 3.3 Nutrient density expressed as the combined percentage of daily recommended nutrient intake (RNI) of the seven nutrients (calcium, iron, selenium, zinc, vitamin A, omega-3 fatty acids, and proteins) that a 100 g fish portion can supply to a child under five years old, a - per market trader category, b - across the top 20 fish taxa traded within the coastal markets, Bars represent the percent contribution a 100 g portion of fish provides of 7 key nutrients relative to the recommended nutrient intake (RNI) for a child under five years. For each nutrient, the value within the bar represents the percentage contribution to RNI

3.4.3 Fish portion sizes and cost of meeting 33.3% nutrient requirement

It was found that a child under five years would need to consume on average, 85 g of fish from a small-scale woman trader to achieve an average of 33.3% RNI across six nutrients (calcium, iron, selenium, zinc, vitamin A, and total omega-3 fatty acids) compared to on average, 92 g, 93 g and 90 g from fish shop traders, men small-scale traders and middlemen/dealers respectively (Table 3.4). Fish taxa-specific portion sizes required to meet an average of 33.3% needs across six nutrients for the top ten most traded fish per trader category are shown in Table 3.4.

Table 3.4 Fish market traders, top 10 most traded fish taxa per trader category, portion sizes needed to meet an average of 33.3% RNI for a child under five years across six nutrients and the portion price in Kenya Shillings and USA Dollars (1 KES ~ USD 0.0067) obtained during the market surveys

Fish market traders	Commonly traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
Women small-scale trader	Danionidae	46	16	0.11
	Cichlidae	81	36	0.24
	Clariidae	104	36	0.24
	Scombridae	78	28	0.19
	Sharks	113	43	0.29
	Siganidae	108	38	0.26
	Lethrinidae	99	37	0.25
	Mixed small marine species	92	44	0.30
	Belonidae	86	32	0.22
	Caesionidae	101	33	0.22
Men small-scale trader	Siganidae	108	40	0.27
	Scombridae	82	29	0.20
	Lethrinidae	99	36	0.24
	Lutjanidae	104	40	0.27
	Others	91	24	0.16
	Octopodidae	59	21	0.14
	Caesionidae	101	31	0.21
	Carangidae	93	33	0.22
	Scaridae	105	32	0.22
	Sharks	113	42	0.28
Fish shop trader	Scombridae	83	30	0.20
	Siganidae	108	36	0.24
	Lutjanidae	104	37	0.25

Fish market traders	Commonly traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Lethrinidae	99	32	0.21
	Mixed small marine species	92	21	0.14
	Carangidae	93	34	0.23
	Scaridae	105	27	0.18
	Loliginidae	61	29	0.19
	Istiophoridae	113	46	0.31
	Octopodidae	59	20	0.14
Middleman/Dealer	Scombridae	80	29	0.20
	Sciaenidae	76	17	0.11
	Sharks	113	33	0.22
	Siganidae	108	33	0.22
	Lutjanidae	104	35	0.24
	Ariidae	75	13	0.09
	Lethrinidae	99	36	0.24
	Lobotidae	81	17	0.12
	Serranidae	96	29	0.19
	Scaridae	105	31	0.21
Weighted average portion size by fish market traders	Women small-scale trader	85	30	0.20
	Men small-scale trader	93	32	0.22
	Fish shop trader	92	31	0.21
	Middleman/Dealer	90	30	0.20

The cost per portion size required to attain an average of 33.3% RNI across six nutrients varied from KES 12 (USD 0.11) to KES 49 (USD 0.44) with a median of KES 30 (USD 0.20) for a median average portion size of 91 g (Fig. 3.4; Table 3.5 in Appendix 2). There was a narrow demarcation of market traders by price per portion size required to meet nutrient needs for a child under five years, highlighting the fact that prices differed mainly by traded fish taxa (Fig. 3.4). Fish taxa in quadrat A of figure 3 are those that are less nutrient-dense but cheap; those in quadrat B are less nutrient-dense but cost more per portion size; those in quadrat C are the most nutrient-dense and cheap while those in quadrat D, are nutrient-dense but costly. All traders appeared to target fish that were most available, hence their similarities and less divergence on traded fish taxa, with the narrow differentiation indicating commonly traded fish across all the market traders (Fig. 3.4). There were some differentiations in traded fish where women small-scale traders overall, sold larger quantities of the most nutritious fishes, including silver cyprinids (Danionidae), anchovies (Engraulidae), sardines (Clupeidae), and mullets (Mugilidae) than the other traders.

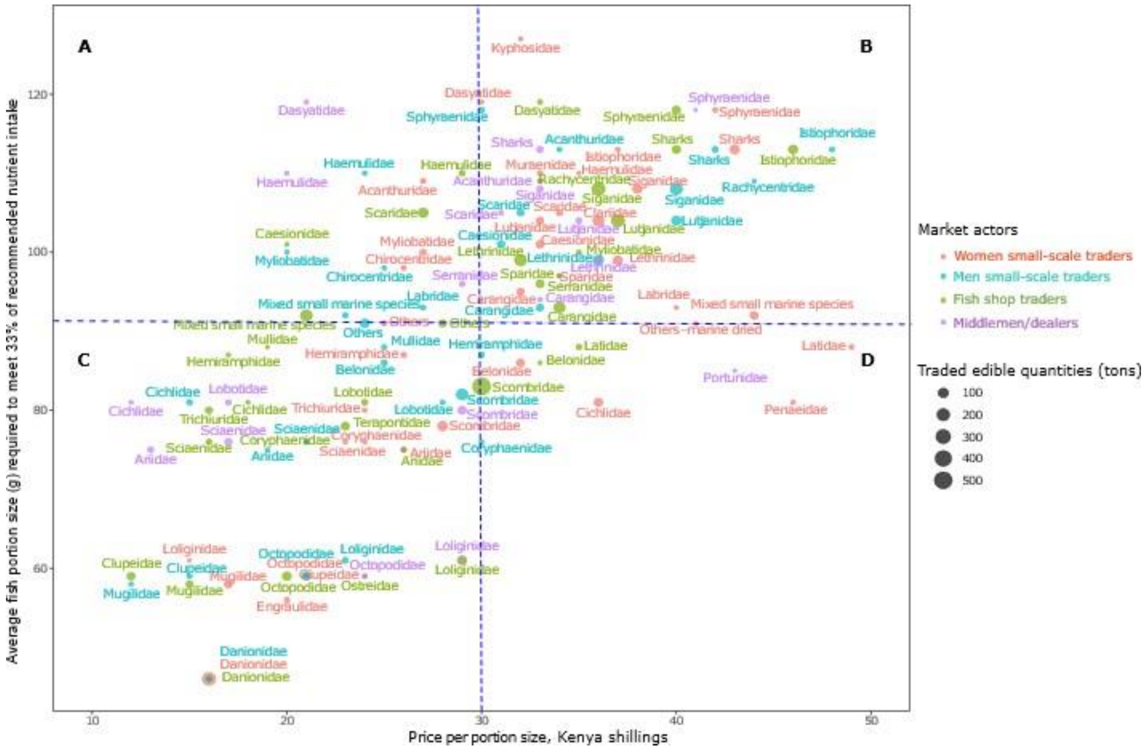


Figure 3.4 Relationship between the fish portion size (g) that is required to meet an average of 33.3% RNI target of a child under five years and price per that portion size presented for all the 47 traded fish taxa across the four market traders (the size of the circle represents the total estimated traded quantities per fish taxa at a market type per year); Quadrat A contains less nutritious but cheap fish, B contains less nutritious but expensive fish; C contains more nutritious and cheap fish and D contains more nutritious but expensive fish. The blue dashed lines represent the median price and portion size

3.4.4 Potential of the traded fish to meet consumption and targeted nutrition requirements

Overall, the fish quantities supplied by the fish shop traders had the potential to meet 129% of the town's population annual per capita fish consumption needs at 10.4 kg/yr followed by small-scale women traders at 84% (Fig. 3.5a). For the targeted nutrition requirements, it was found that the total quantities of fish traded by the women small-scale traders was sufficient to meet over 80% of the recommended nutrient intakes across all the nutrients, except vitamin A, for all children under five years old within the three towns of Malindi, Mtwapa and

Ukunda (Fig. 3.5b). The fish shop traders sold sufficient quantities of fish to meet over 33% of nutrient requirements for calcium, iron, selenium, zinc, omega-3, and protein whereas the men small-scale traders and middlemen/dealers sold sufficient quantities of fish to meet 33% of nutrient requirements across 3 and 2 nutrients respectively for the target children under five years (Fig. 3.5b).

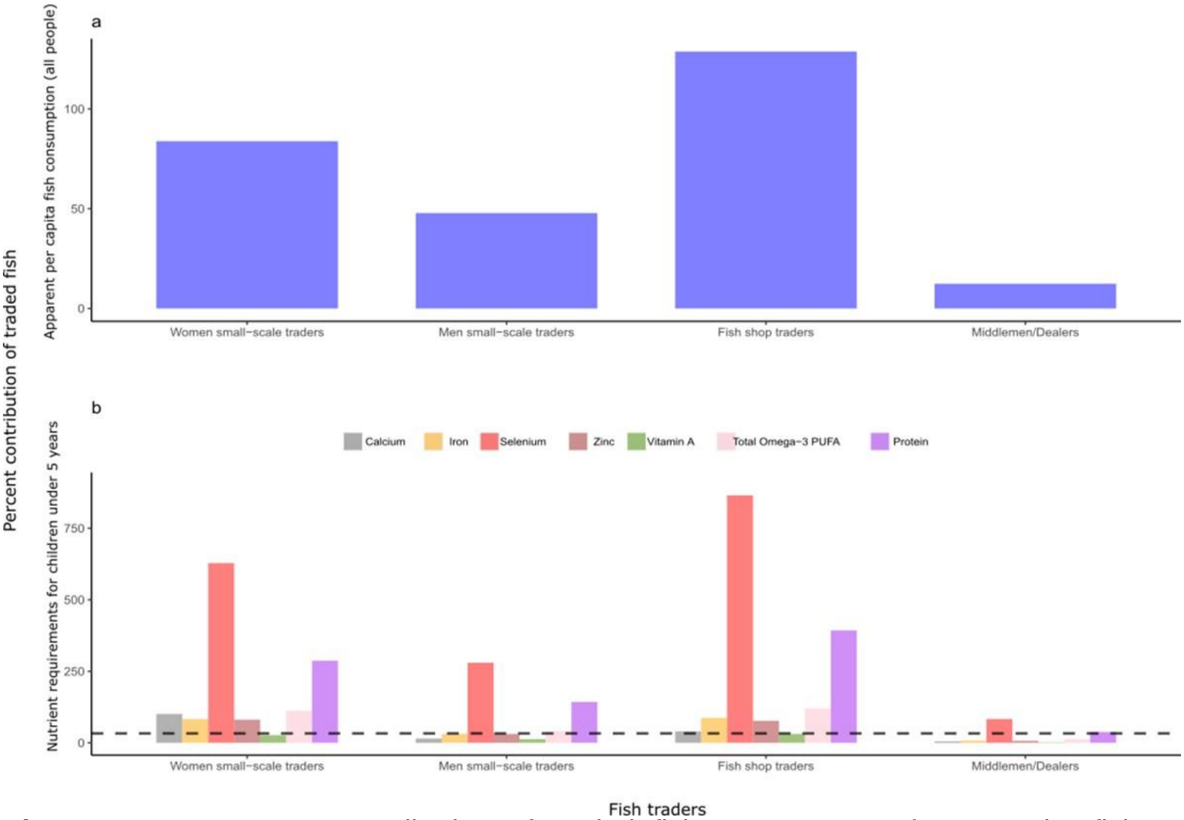


Figure 3.5 Percentage contribution of traded fish to a – annual per capita fish consumption of all people within the market locations, b – nutrient requirement of seven nutrients (calcium, iron, selenium, vitamin A, zinc, omega-3 fatty acids and protein) for the target population of children under five years of age residing in the three market towns, the dashed line indicates the 33% cut-off

3.5 Discussion

Findings in this chapter reveal that traded fish at coastal markets in Kenya can support local fish consumption and nutrition security, with the most nutrient-dense fish taxa found to be the cheapest and offered by all traders. This is evidenced in the diversity of fish taxa traded at different prices that present different alternatives for different consumer preferences and financial statuses.

3.5.1 Coastal fish markets avail diverse fish taxa, quantities, and prices

Diverse fish taxa are traded in different quantities and prices across the four categories of market traders. The observation of the small fish quantities traded by women small-scale traders could be attributed to the need to sell their fish before it gets spoilt, due to a lack of cold storage and post-processing options (except deep frying and drying) that can extend shelf-life, or limited financial ability to purchase more fish when demand is high (Matsue *et al.*, 2014; McClanahan and Abunge, 2017). The range of fish quantities traded daily by the different market traders falls within the 1 to 100 kg daily fish volumes transacted by fish traders along the Kenyan coast (Wamukota, 2009), and that of women small-scale traders that varies between 1 and 18 kg of fish per day, with a few dealing in up to 50 kg (Matsue *et al.*, 2014). Nonetheless, it has been indicated that fish purchasing capacity of women small-scale traders may decline with rising fish prices which may compel them to cut down on quantities of fish traded (Matsue *et al.*, 2014).

The fish prices per kilogram were comparable across all traders, suggesting there is little variability in the price of fish, but traders that target different consumers are able to change the affordability of fish by altering the sizes sold. For example, fish sold by women small-scale traders are generally considered cheaper (Matsue *et al.*, 2014; McClanahan and Abunge, 2017), this is likely because women small-scale traders sell their fish in smaller portions (either pieces or bundle measures) making each exchange more affordable (Thilsted *et al.*, 2016). However, when these smaller portions are aggregated into the standard unit of a kilogram, the price does not significantly differ from the other three market traders. Findings from this study reflect to some extent why the women small-scale traders prefer cheaper small fish and narrow-bodied mixed sizes of other fishes, the latter being cut into several small portions that attract low-income buyers who prefer smaller pre-processed fish portions, thus sustaining profits for this market category as well as offering affordable fish to poor or low-income households. The price range per portion size needed to achieve an average of 33.3% nutrient requirement could be affordable to diverse consumers with different socio-economic statuses. This is important since Kenya's average monthly income ranges widely from approximately KES 30,000 – 150,000 (USD

250-1200) and an indicative minimum wage of KES 10,000-14,000 (USD 80-120) (TimeCamp, 2024).

The fish taxa traded by all traders reveal fish taxa that are characteristic of Kenya's small-scale fisheries (Hicks and McClanahan, 2012; Ndarathi *et al.*, 2020; Omukoto *et al.*, 2018), which are key to harnessing multiple nutritional benefits (Bernhardt and O'Connor, 2021; Kilpatrick *et al.*, 2017). Further, the observed associations of taxa and market traders seem to mirror similar observations to studies that have investigated fish trade in Kenya (Kimani *et al.*, 2020c; McClanahan and Abunge, 2017; Ndarathi *et al.*, 2020). The diversity of fish traded is key to providing nutritionally rich fish and fish products that are culturally preferred and easily accessed by the poor and other consumers (Belton and Thilsted, 2014), since low diversity can create constraints on consumer choice (Arthur *et al.*, 2021).

3.5.2 Traded fish contain beneficial nutrients for supporting nutrition security

This study established that the nutrient densities of traded fish highlight the significant role of fish as a nutritious food product (Hasselberg *et al.*, 2020; Hicks *et al.*, 2019; Maire *et al.*, 2021; Robinson *et al.*, 2022a; White *et al.*, 2021). Although for many the motivation for fish trade in Kenya is to generate economic profits (Kimani *et al.*, 2020c; McClanahan and Abunge, 2017), it can also represent a livelihood activity (Matsue *et al.*, 2014; Wamukota *et al.*, 2014). Findings from this study highlight a third contribution of traded fish in coastal Kenya; as a key source of local nutrition for people's health. This study adds to a growing body of literature on the role of subnational markets in making fish available and affordable for human consumption (Bundala *et al.*, 2020; de Bruyn *et al.*, 2021; Hotz *et al.*, 2015; Thakwalakwa *et al.*, 2020). This information on market traders mediating access to and availability of nutritious fish is foundational to supporting policy interventions that are geared towards improving the contribution of fish markets to food and nutrition security.

There were variations in fish nutrient density across traders, all demonstrating that they do provide fish taxa that can be consumed in smaller quantities (average 85 – 93 g) yet achieving significant nutritional outcomes at an average of 33.3%

requirement across the six important nutrients. These data for Kenya are consistent with global estimates for reef fish indicating a 90 g portion on average is needed to meet nutritional requirements across six nutrients (Hicks *et al.*, 2021). These findings are further supported by a recent discussion on use of animal sourced foods as part of healthy, sustainable, and ethical diets that highlights small quantities of small dried fish (6 g), dried/smoked fish (15 g) and fresh/frozen fish (68 g) were sufficient to meet 33.3% of requirements averaged across six nutrients (Beal *et al.*, 2021; White *et al.*, 2021; Leroy *et al.*, 2022). These studies focused on children under two years meeting requirements for calcium, iron, zinc, vitamin A, vitamin B12, and folate, whereas my study focused on children under five years meeting requirements for calcium, iron, selenium, zinc, vitamin A, and omega-3 fatty acids, nutrients for which data were readily available at species level and which are essential nutrients for children's growth in coastal Kenya. My findings illuminate the fact that the fish currently made available and accessible by the four market categories have potential to ameliorate hidden hunger among children under five years within the three coastal market towns. This is an important contribution to the knowledge of nutrient content and can help consumers switch their species preferences and be flexible to eating available and accessible nutritious fish offered by the different market traders.

3.5.3 Subnational fish markets supply fish that can be harnessed to meet consumption and nutrient requirements

The fish quantities traded at the coastal markets supply enough fish to meet the recommended per capita fish consumption of 10.4 kg/yr based on a 100 g serving per day for two days per week (Willett *et al.*, 2019). Based on the combination of six nutrients assessed for the target population, the fish supplied by the different traders provide varied amounts of nutrients with potential to partly meet the nutrient requirements for children under five years. The observation that women small-scale traders supplied fish that can meet over 80% of the recommended nutrient intakes across six of the nutrients for all children under five years old could be linked to their trade in nutrient dense fish such as the small pelagic cyprinids (family Danionidae), mullets, anchovies, and clupeids (mainly sardines) (Robinson *et al.*, 2022c; Isaacs, 2016; Byrd *et al.*, 2021a). Interestingly, apart from being nutrient-dense, these species tend to cost less (Robinson *et al.*, 2022c). The variability in nutrient adequacy by different market traders could be attributed to differences in the fish taxa traded with implications for access by different income groups. Availability of diverse fish taxa appear to be limited by quantities traded where the most traded volumes were by the fish shop traders. It was clear that the small pelagic cyprinids (family Danionidae) constituted the most traded fish among women small-scale traders, while the family Scombridae dominated the fish shop traders, indicating that preference of what to consume may be compromised by scarcity of desired fish taxa on the market.

While traded fish diversity would be important to meeting diverse consumer preferences, market availability may dictate the options a consumer has access to (Wamukota, 2009). For example, women small-scale traders have been mainly associated with small-bodied marine and freshwater species (McClanahan and Abunge, 2017; Wamukota, 2009; Wamukota *et al.*, 2014; Abila, 2005). Additionally, it was found that all traders potentially traded in mixed small marine species albeit in different quantities. Therefore, there is a need to mainstream the important role played by the diverse market traders due to their uniqueness and complementarity with each other to ensure availability and accessibility of fish. Women small-scale traders tend to bring fish closer to the target consumers' residence while fish shop traders sell fish in shops which require people to travel, and depending on location, and distance, some consumers may opt to buy from the women traders who have brought the fish closer home. Some men small-scale traders were likely to display fresh fish for trade at nearby markets while middlemen/dealers worked with delivery of orders that they aspired to meet or transact at the landing site level upon fish being landed by the fishers.

Findings of this chapter reveal that Kenyan coastal fish markets contribute to availability and accessibility of fish that is nutrient rich, socio-economically accessible and within physical reach by resident coastal populations. However, to achieve this, the market traders seem to rely on a mix of trader attributes that is reflected in different fish quantities transacted. These attributes include level of economic investment and technology (processing, and storage), diversity of products, proximity to consumers, monetary, nutritional and cultural value of traded fish (Short *et al.*, 2021). Consequently, these attributes can play out as key entry points for improved nutrition-sensitive fish trade across the four market categories. The narrow differentiation among traded fish taxa could largely be attributed to the higher dependence of the traders on similar sources of fish, majorly the coastal small-scale coral reef fishery. Therefore, management of these fisheries can be tailored to achieve nutritional benefits without compromising biodiversity concerns and sustainability through nutrition-sensitive ecosystem-based approach to fisheries management or attempting novel approaches such as the multi-species maximum nutrient yield (mMNY) model that has been found to have the potential to reduce nutrient gaps for coastal populations, thus maximizing the contribution of wild-caught fish to food and nutrition security (Robinson *et al.*, 2022b). Another option would be to facilitate market traders' coexistence by applying management for intermediate resource levels to have high fisheries production, catch and fish body size diversity (McClanahan and Abunge, 2017).

3.6 Conclusions and policy implication

This study revealed the dimension of nutritional security from fish trade that would require mainstreaming in food policy narratives by recognizing the role played by different market traders to supply important nutrients for human health. The study proposes the mainstreaming of fish markets within the framework of agricultural value chains, to maximize the attainment of nutritious fish. There is growing momentum for food system transformation (Arthur *et al.*, 2022; FAO, IFAD, UNICEF, WFP and WHO, 2021). Therefore, the research findings provide an empirical basis of how traded fish could be taken up to transform fish markets to be nutrition-sensitive. However, it is advised that while this is being considered, management for stability and sustainability should be central since over-reliance on one or few fish taxa may lead to their decline like has been reported for the declining freshwater silver cyprinid in Lake Victoria (Aura *et al.*, 2020). Further, whilst fish traders are significant traders in resource use, their incentives, actions, behaviors, decisions, and willingness to comply with management interventions can either promote or demote efforts to achieve sustainability (McClanahan and Abunge, 2017). Therefore, policy decisions around mainstreaming fish, fish trade, and nutritional outcomes will require engaging multiple stakeholders to achieve the goal of a sustainable food system framework as envisaged.

This information is useful in shaping peoples' perceptions about traded fish as a nutritious food that should be integrated into the overall food production agenda. I propose mainstreaming the activities of the four fish market categories towards improving nutrient-rich fish supplies for local populations. This could help contribute to achieving food and nutrition security commitments that have been made by the national and county governments, as well as international commitments such as SDG 2 on achieving food security and improving nutrition by 2030. While this study focused on meeting recommended nutrient intakes for children under five years, these can be upscaled to other vulnerable population groups dependent on needs assessment.

Chapter 4. Social processes and power dynamics drive food and nutrition security in coastal communities interacting with tropical small-scale fisheries

4.1 Abstract

In chapters 2 and 3, I elucidate various factors associated with the uptake of fish across the availability and access pillars of food and nutrition security in the context of supply and trade. However, an understanding of people's decision-making (agency) processes and how power dynamics shape access to fish are needed to ensure food and nutrition security are improved. Facilitating access to fisheries resources and ensuring people have the agency to attain nutrition is pivotal to alleviating hunger and ensuring healthy lives. However, there is a paucity of studies examining people's agency in becoming food and nutrition secure. This is a particular gap in Sub-Saharan Africa where coastal communities have a high prevalence of nutritional deficiencies, despite their proximity to nutrient-rich fisheries. To address this gap, I sought to establish how social-cultural, economic, and environmental factors influence people's access to sufficient quantities of nutritious, and culturally appropriate fish. I developed an interdisciplinary mixed methods approach, that combines a Theory of Access with the Capabilities Approach to investigate what influences people's ability to benefit from the food and nutrition contribution of fisheries. I used social survey data from 116 key informant interviews and 547 household interviews across six coastal villages to elucidate what enables or constrains access and agency. Seven access mechanisms and 13 conditions for agency emerged that were enabling, constraining, or both although 4 access mechanisms and 6 conditions for agency were identified as the most dominant. Disentangling what enables and constrains access and agency provides helpful insights as entry points to leverage the transformation of small-scale fisheries governance and policy frameworks by relevant practitioners and policymakers. Further research to explore the effectiveness of specific interventions at increasing access and expanding agency is recommended to support food and nutrition security.

In preparation - Omukoto JO, Allegretti A, Hicks CC, Social processes and power dynamics drive food and nutrition security in coastal communities interacting with tropical small-scale fisheries. *World Development Journal*

4.2 Introduction

Tropical small-scale fisheries resources have the potential to better support food and nutrition security within coastal communities (Arthur *et al.*, 2022; Canty and Deichmann, 2022; FAO, 2022b; de Bruyn *et al.*, 2021; Tacon *et al.*, 2020; Koehn, 2019; Allegretti and Hicks, 2022). These resources provide a readily available and cheap source of protein and bioavailable micronutrients in many countries (Golden *et al.*, 2016; Hicks *et al.*, 2019; HLPE, 2014; Kawarazuka and Béné, 2011; Maire *et al.*, 2021; Robinson *et al.*, 2022a). But fish and particularly small-scale fisheries remain understated in national, regional, and global food security policies (Béné *et al.*, 2015; Bennett *et al.*, 2021a; FAO, 2020; Hicks *et al.*, 2019; Koehn, 2019; Allegretti and Hicks, 2022). Kenya's coastal counties rank among those that are most food and nutrition insecure in the country with food poverty levels above 60% (Lokuruka, 2020) and high malnutrition rates of above 26% (Cartmill *et al.*, 2022). Within small-scale fisheries, fish is increasingly treated as a commodity and source of income (Fiorella *et al.*, 2014; Wamukota *et al.*, 2014; Wamukota and McClanahan, 2017; Allegretti, 2019). However, due to the proximity of coastal communities to the Indian Ocean, and its nutritious fishery resources, fish could play a larger role in supporting nutrition security at the household scale, highlighting an opportunity to place fish at the centre of food and nutrition policy agendas (Bennett *et al.*, 2021a; Kamau-Mbuthia *et al.*, 2023). However, this may be hampered by limited access and would require an understanding of the conditions for agency that may need to be addressed to ensure fish is utilized to alleviate nutrition insecurity.

The challenges of accessing food and making decisions about what food to consume emerge in people's daily living whereby individuals, households, and communities must make difficult decisions about meeting their food and nutrition security needs (Chan *et al.*, 2019; Hasselberg *et al.*, 2020; Lokuruka, 2020). Therefore, an understanding of the mechanisms of accessing food and conditions for decision-making on food resources is needed for the delivery of positive nutritional outcomes (HLPE, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2023). By examining how people within vulnerable communities gain access to fish, I aim to fill the gap by providing empirical data supporting the need to mainstream fish and small-scale fisheries in food policy. The assurance of access and protection of agency requires socio-political systems that uphold governance structures enabling the achievement of food and nutrition security for all and meeting national goals (e.g., Kenya's Agenda 4 on food security), supporting a regional agenda (African vision 2063) and global commitments such as SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture) and SDG 3 (ensure healthy lives and promote wellbeing for all at all ages). This is particularly demanding considering the need to "build back better" as communities and households emerge out of the effects of the global covid-19 pandemic and the ongoing Russia-Ukraine war that has exacerbated the food and nutrition insecurity situation (Lau *et al.*, 2021; Panghal *et al.*, 2022; Love *et al.*, 2021; FAO, IFAD, UNICEF, WFP and WHO, 2023; Ben Hassen and El Bilali, 2022).

I carried out this research to answer the question: "*How do social-cultural, economic, and environmental factors influence people's access to fish, and their agency to acquire sufficient quantities of nutritious, and culturally appropriate seafood within the coastal communities?"* To do this, I conducted 116 key informant interviews that examined the mechanisms of access and conditions for agency that influence a community's or individual's access to and decision-making surrounding obtaining fish for consumption. I further carried out 547 household surveys to examine the importance of the 4 mechanisms of access and 6 conditions of agency that were identified as most dominant during the key informant interviews in the identified coastal communities. I aimed to address the urgent need for strengthening and consolidating conceptual thinking around fish for food and nutrition security to prioritize the right to fish for food, widen our understanding of fish for food and nutrition security, and adopt a food systems analytical and policy framework incorporating access and agency (HLPE, 2020).

4.3. Theoretical approach

To address the research question posed in this chapter, I used both the Capabilities Approach (Sen, 1989) and a Theory of Access (Ribot and Peluso, 2003) to simultaneously reveal the social, environmental and political-economic perspectives that shape people's abilities to benefit from resources and achieve a diverse development agenda (Myers and Hansen, 2020) including human health (Nussbaum, 2013). This study acknowledges that access and agency are two intricately linked pillars of food and nutrition security. The implication of this is that there will be contexts of overlap among factors shaping both access and agency. Consequently, I used A Theory of Access to unravel the power structures (the strands) contained in the bundles of power that shape access (Ribot and Peluso, 2003; Peluso and Ribot, 2020). This theory makes an invaluable contribution to understanding the power dynamics of access to resources (Myers and Hansen, 2020) such as fish as an important nutritious food by specifying the different types of mechanisms of access and how these mechanisms shape access. However, A Theory of Access has been critiqued for not adequately theorizing agency (Koch, 2008). Therefore, I address this limitation by applying The Capability Approach through the lens of conversion factors that are useful in mediating the ability of people to convert resources and consumption into achieved functionings (Chiappero *et al.*, 2018; Sen, 1985a, 1999).

I unravel the factors influencing access and agency by using A Theory of Access and The Capability Approach respectively as schematized in Fig. 4.1 to gain a holistic assessment and understanding of the power dynamics and social processes influencing access and agency in coastal Kenya. The schematic representation of the intersection of the two approaches guided the investigations of the mechanisms of access and conditions for agency (Fig. 4.1). The schema shows how capabilities (expressed through peoples' choices and freedoms to achieve desired functionings) are converted to valued food and nutrition outcomes. Importantly, this illustration attempts to draw attention to how greater attention to access (contained within the capability space) including how it relates to agency (which extends beyond having access to include decision-making about converting those abilities to desired beings or doings) lead to achieving human nutritional aspirations and targets. The schematic diagram attempts to unpack the relationships between conditions for agency (conversion factors) and the mechanisms of access (10 access strands of power) to reveal how achieving nutritional outcomes is pursued. This helped identify the two themes based on mechanisms of access (1. rights-based access mechanisms, and 2. structural and relational mechanisms of access) and three themes based on the conditions for agency (1. environmental, 2. personal, and 3. social conversion factors) that would inform the process of transforming small-scale fish food system. I encapsulate the mechanisms of access from A Theory of Access within the capability space since The Capability Approach has been described as a general theory that includes A Theory of Access (Ballet *et al.*, 2020). Under section 4.3.1 and 4.3.2, I discuss a Theory of Access and the Capabilities Approach (concept of conversion factors) respectively. Taken together, A Theory of Access offers enough mechanisms to examine the complexity of power dynamics (Ribot and Peluso, 2003), while the Capability Approach through the conversion factors enriched an understanding of the linkage of human agency in analyses of factors that influence social inequality (Hvinden and Halvorsen, 2018) related to food and nutrition security. Considering my research focus was on how people could convert fish into beneficial nutritional outcomes, I apply conversion factors as conditions for agency that influence how people may translate nutritious fish through consumption to achieve nutrition security.

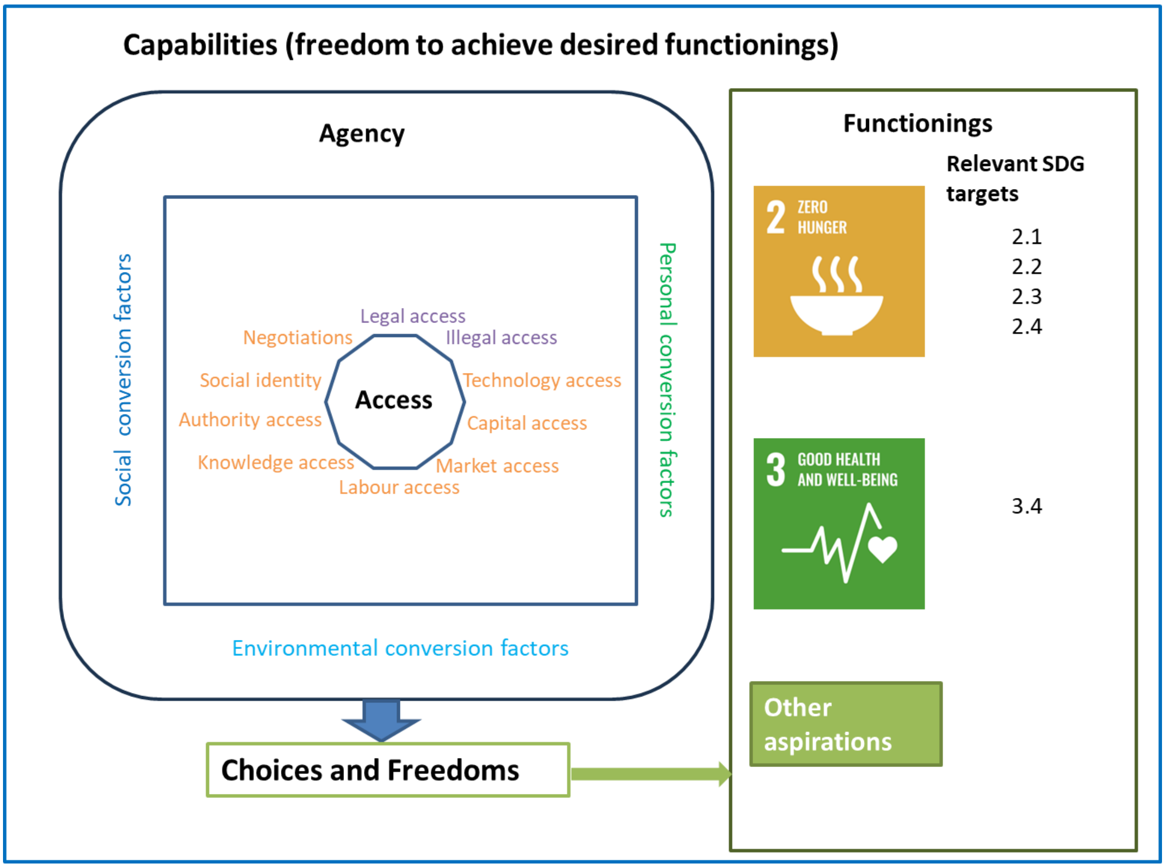


Figure 4.1 Schematic representation of the intersection between the Capabilities Approach and the Theory of Access as used in the current study to reveal mechanisms of access and conditions for agency that drive delivery of sustainable development goals 2, 3 and other aspirations, and maximize the contribution of aquatic food systems through enhanced abilities and agency engagement. The orange fonts refer to structural and relational mechanisms of access while purple refers to rights-based mechanisms that fall within the premise of Theory of Access. Dark blue font, light blue font and green font reveal conversion factors articulated from the Capabilities Approach

4.3.1 A Theory of Access

A Theory of Access is a useful framework for understanding how people gain benefits from things (or resources) with a broader focus on power dynamics (Ribot and Peluso, 2003). A Theory of Access has been quite instrumental in expanding an understanding of access beyond property by exploring notions of power (Myers and Hansen, 2020). Therefore, I used a Theory of Access to provide a simplified understanding of the mechanisms that influence people's ability to access fish. This framework clarifies the role of power relations in mechanisms of access (Peluso and Ribot, 2020; Myers and Hansen, 2020) and can be instrumental in guiding the mapping, understanding, and analysis of "how" and "why" people or institutions in power relations can gain or be excluded from using resources (Ribot and Peluso, 2003; Mutea *et al.*, 2020). Ribot and Peluso's framework has its merit in the conceptual shift away from a focus on legal rights and their valuable efforts to identifying the varied and multiple mechanisms by which people gain access and the underlying power relations shaping access (Myers and Hansen, 2020). Critiques of a theory of access have indicated several weaknesses and concerns. First, it does not define in detail what power is nor does it present an in-depth discussion of power (Westermann, 2007). Secondly, it has been critiqued for not being comprehensive around the conceptualization of access mechanisms such as differentiating between "structural" and "relational" (Koch, 2008). Thirdly, it has been described as ambiguous in describing the changing nature of power (Koch, 2008). Despite the foregoing, a Theory of Access has been used in many studies across the world in a wide range of research subjects to explain and examine access to natural resources (Myers and Hansen, 2020; Aguirre, 2013; Hicks and Cinner, 2014; Ballet *et al.*, 2020). Therefore, I used a Theory of Access to identify and describe how the mechanisms of access (revealed as the constitutive strands of bundles of power) influence the abilities of people to access fish for food and nutrition security.

4.3.2 The Capability Approach and concept of conversion factors

The Capability Approach envisages conversion factors as the structures constraining or enabling the conversion of capabilities into functionings (Hvinden and Halvorsen, 2018). Conversion factors are a key element of the capability approach with their role of mediating the ability of individuals to convert resources and consumption into capability sets and achieved functionings (Sen, 1985a, 1999; Chiappero *et al.*, 2018). I applied the concept of conversion factors to gain an understanding of the variability of constraining and enabling conditions, including unveiling what may be unexpected (Abreu *et al.*, 2023). The conversion factors reveal conditions for agency (broadly categorized as environmental, personal, and social) that shape the extent to which individuals, who may be endowed with similar resources can attain comparable capability sets (Abreu *et* *al.*, 2023). I used conversion factors to reveal how individuals with differing freedoms act (agency inequalities) as relationally embedded in environmental, personal, and social contexts (conversion factors) thus making visible the processes through which individuals with varying agency harness fish for nutritional security. Conversion factors can be considered as conversion processes (Hvinden and Halvorsen, 2018), in which case they have been shown to shape or influence people's freedoms to achieve valued beings, doings, and their ability to change social structures around them, thus affecting their active agency (Yerkes *et al.*, 2019). Agency can be contained into a capability approach framework as a structural factor that enhances or limits a person's ability to translate resources and consumption into valuable capabilities, or as a capability in itself, depicting the ability to be in control of one's environment, or to be involved in critical reflection about the planning of one's life (Nussbaum, 2000). Agency can also be considered as a separate dimension of vital value (Sen, 1985b), thus indicating the distinction between 'wellbeing freedom', which includes a person's capability set, and 'agency freedom', defined as 'what the person is free to do and achieve in pursuit of whatever goals or values he or she regards as important' (Abreu *et al.*, 2023).

4.4. Materials and methods

4.4.1 Study sites and context

With the help of one research assistant, I conducted key informant interviews at three coastal villages (S1. Mijikenda - Malindi, S2. Shimoni, and S3. Kibuyuni) and household surveys in three additional adjacent villages (T1. Watamu, T2. Mkwiro and T3. Vanga), with the latter 3 villages targeted to gain further insights from independent but related fishery-adjacent communities (Fig. 4.2). The villages were purposively selected following a non-probability, convenience design based on their proximity to marine and coastal fishery resources (within 4-16 m above sea level) and high reliance on fishery resources by majority of the residents. Table 4.1 summarizes the main characteristics of the 6 villages with Mijikenda - Malindi and Watamu located north of Mombasa city while Shimoni, Kibuyuni, Mkwiro and Vanga are located south of the city.

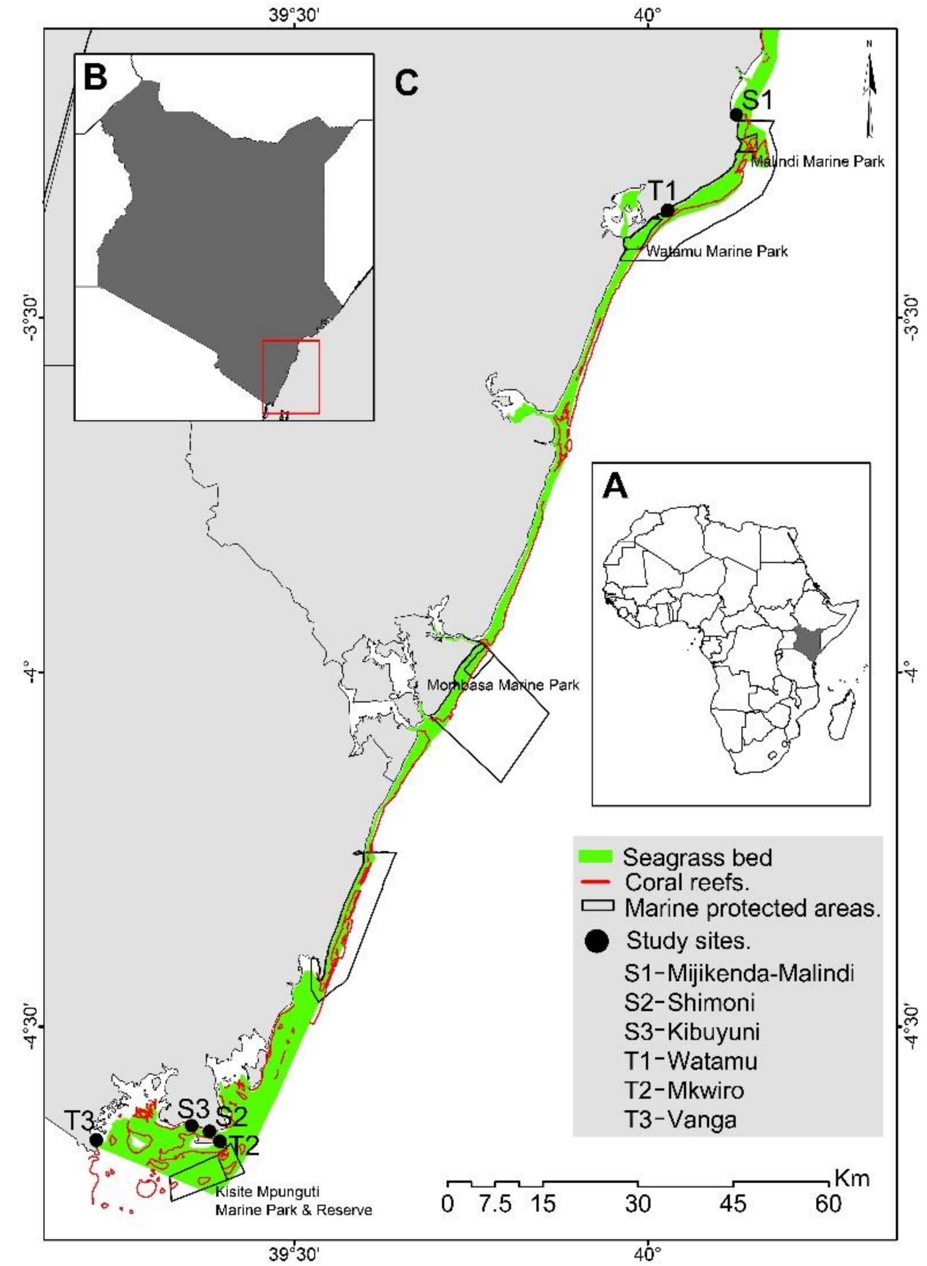


Figure. 4.2 Map of the African continent (A) showing the location of Kenya (shaded) and map of Kenya showing part of the Kenya coastline (B) and the expanded Kenya coastline (C) showing the 6 villages where the social surveys – S1, S2, S3, and household surveys – T1, T2, T3 were conducted

Table 4.1 Selected characteristics of the six study villages where the social surveys and household interviews were conducted

Characteristics	Mijikenda-Malindi	Shimoni	Kibuyuni	Watamu	Mkwiro	Vanga
Geographic position (estimation from Google Earth Pro)	3°12'51.81"S; 40°07'22.67"E	4°38'49.79"S; 39°22'49.49"E	4°38'19.98"S; 39°20'26.96"E	3°21'12.85"S; 40°01'17.97"E	4°39'49.32"S; 39°23'45.37"E	4°39'35.30"S; 39°13'07.86"E
Mean altitude (m)	4	8	8	6	16	8
Main livelihood activities	Fisheries production and subsistence livestock keeping	Fisheries production, subsistence farming and livestock keeping	Fisheries production, subsistence farming, and livestock keeping	Food-related businesses, other businesses and informal employment	Fisheries production, food-related businesses and other informal businesses	Food-related businesses, other informal businesses, fisheries production and subsistence farming
Men respondents	29	35	23	-	-	-
Women respondents	6	8	15	152	143	252
Total number of key informants /Household respondents	35	43	38	152	143	252

4.4.2 Key informants' qualitative approach and participants selection

Qualitative in-depth key informant interviews were conducted by me and one trained female social science research assistant (to navigate any cultural gender issues that arose) between 8th March and 17th April 2021. We interviewed 116 key informants (87 men and 29 women) using preset interview guide questions that had been pretested at a different locality (i.e., Mtwapa landing site). The interviewed participants were first selected purposefully to reflect diversities in age, gender, ethnicity, religion, marital status, and occupational profiles (Table 2) (Palinkas *et al.*, 2015). To achieve saturation for the social survey interviews (Saunders *et al.*, 2018), the criteria-based purposeful sampling was followed by snowballing referrals (Naderifar *et al.*, 2017) where additional representation was found necessary and guided by information provided by the fisheries co-management representatives, village administrative heads, or chiefs and interviewed key informants.

Table 4.2 Selected demographic profiles of the interviewed key informants who participated in the social surveys in coastal Kenya (n = 116)

Demographics	**Numbers**	**%**
Sex		
Men	87	75
Women	29	25
Age group (years)		
20-29	12	10
30–39	25	22
40–49	26	22
50–59	31	27
>60	22	19
Religious affiliation		
Islam	78	67
Christian	26	23
None	12	10
Marital status		
Single	11	9
Married	98	84
Widow	3	3
Engaged	1	1
Separated	3	3
Residence village		
Shimoni	43	37
Kibuyuni	38	33
Mijikenda	35	30

Occupational orientation		
Fishery related occupations	83	72
Non-fishery related occupations	33	28

During the key informant interviews, the respondents were prompted to contribute their perspectives on access (including general perceptions, availability, and access) and agency (including decision-making by people involved, governance strategies, institutions, and leadership) in the context of how these shape fish acquisition and consumption practices. We conducted the interviews in Kiswahili (the national language) and each interview lasted between 45 and 90 minutes, depending on the respondents' approach to answering or sharing information, the time commitment by the respondent, and the respondents' knowledge about the prompt question. All interviews were audio recorded with permission from the participants and later manually transcribed to ensure their accuracy before exporting to NVivo (released in March 2020) for qualitative data analysis.

4.4.3 Household surveys, quantitative approach to examine the influence of dominant mechanisms of access and conditions for agency

The household surveys carried out to examine the relevance of the 10 most dominant mechanisms of access and conditions for agency were post-key informant interview investigations done after analysis of the key informant interviews' qualitative data. This involved a Likert scale, asking respondents' level of agreement with the influence of 4 mechanisms of access and 6 conditions of agency, and was done as part of a detailed household survey investigating fish consumption patterns and food security between 14th December 2022 and 3rd March 2023 (Chapter 5). We interviewed 547 respondents who were household members responsible for the preparation of meals the previous day. We selected the households through a systematic approach following an informed selection of the first household in each village by the village chairman and guide. We interviewed respondents in every second household (with replacement if the respondent was not found) for Watamu and Mkwiro villages which had low numbers. In Vanga, we interviewed respondents in every fourth household. We interviewed the respondents using 5-point Likert scale questions (strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, and strongly agree) to whether the 4 mechanisms of access (financial access, market access, fishing technological access, and legal access) and 6 conditions of agency (fish availability and adequacy, decision-making dynamics, cultural norms, fish palatability attributes, fish preparation, preservation and cooking knowledge, and consideration of fish as a healthy diet) influenced the household’s ability to obtaining fish for home consumption.

4.4.4 Data analysis

4.4.4.1 Key informant interviews qualitative data analysis

The key informant interviews were analyzed following the principles of the five-level qualitative data analysis (The Five-Level QDA) method (Breakwell *et al.*, 2012; Woolf and Silver, 2018) as outlined in the analytical conceptual framework (Fig. 4.3). The five-level qualitative data analysis involved working at the strategy levels (Levels 1 and 2) to prepare the data in line with research objectives, methodology, and the guiding conceptual framework. Once an analytic task had been identified and expressed in its own units, it was taken through its cyclic one-way-only journey around the Five-Level QDA process (Woolf and Silver, 2018). My unit of analysis was access and agency which I examined as guided by a Theory of Access and the Capabilities Approach respectively.

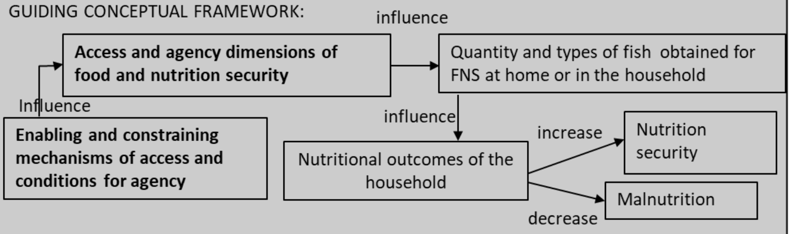
ACCESS AND AGENCY ASSESSMENT WITHIN COASTAL COMMUNITIES OF KENYA		
Level 1: OBJECTIVES and METHODOLOGY	OBJECTIVES: To examine social-cultural, economic, and environmental factors influence people's access to fish, and their agency to acquire enough nutritious, and culturally appropriate seafood within the coastal communities.	
	METHODOLOGY: Social survey interviews with key informants and guided by the Theory of Access and Capability approach. Used pragmatist/mixed /merged methods.	
Level 2: OVERALL PLAN	GUIDING CONCEPTUAL FRAMEWORK: 	
Level 2: TASKS	**Level 3: TRANSLATION of TASKS into TOOLS**	**Level 4 & 5: SELECTED or CONSTRUCTED TOOLS**
Examine the mechanisms of access to fish for food and nutrition security	UNITS: Participants as the cases in the study COMPONENTS Interview responses from each EXPLANATION Organization & reading through all responses to identify access themes.	Reading through the interviews and coding for access – thematic analysis (TA) and content analysis to produce themes and subthemes.
Examine the conditions for agency about fish for food and nutrition security	UNITS: Participants as the cases in the study COMPONENTS Interview responses from each EXPLANATION Organization & reading through the responses to identify agency themes.	Reading through the interviews and coding for agency – thematic analysis (TA) and content analysis (CA) to produce themes and subthemes.
Synthesize the mechanisms of access and conditions for agency into enablers and constraints	UNITS: Participants as the cases in the study COMPONENTS Interview responses from each EXPLANATION Organization & reading through the responses to identify the enablers and constraints.	Reading through the interviews and coding for enablers and constraints – thematic analysis (TA) and content analysis (CA) to produce themes and subthemes.

Figure 4.3 The analytical conceptual framework used for the key informant interviews data analysis using the five-level qualitative data analysis (The Five-Level QDA) process

I used both thematic analysis (TA) and content analysis (CA) to analyze the key informant interviews. The data was systematically coded deductively using the six steps process of thematic analysis (Braun and Clarke, 2006; Byrne, 2021; Kiger and Varpio, 2020) whereby similar codes were identified and merged to produce main themes from the sub-themes and respondents' narratives related to factors influencing access and agency about fish consumption. Thematic and Content analysis was undertaken using the NVivo software program (QSR International).

Thematic analysis method was useful for identifying, analyzing, and reporting patterns (themes) within the data and minimal organization and description of the dataset in detail (Byrne, 2021; Han *et al.*, 2021). This approach was used since it is flexible and can be used with different research designs. Thematic analysis is good for exploring patterns across qualitative data from participants and is often useful for analyzing interviews (Kiger and Varpio, 2020). Themes are the overarching categories of common data across multiple participants. All textual data contained in a theme tells a story about that theme and is somehow related, representing different dimensions of a phenomenon (Byrne, 2021).

Content analysis can be used as a quantitative or qualitative method of data analysis (White and Marsh, 2006). This study applied content analysis, to achieve quantification of data including count of instances of codes (frequency of mentions) and obtaining summaries of the number of cases (respondents) and initial codes (narrations) associated with the interview data. Consequently, the responses were coded, codes synthesized into subthemes, and the subthemes framed into themes, guided by a Theory of Access and the Capabilities Approach frameworks.

4.4.4.2 Household survey, quantitative data analysis

I examined the Likert-scale scores on perceptions of the importance/influence of the 4 mechanisms of access and 6 conditions of agency for internal consistency and reliability using Cronbach's alpha (ɑ) test (at least ɑ = 0.7 (70%)) using the equation below (Cronbach, 1951; Price, 2017).

$$\alpha = \frac{k}{k-1}(1 - (\sum \sigma i^2)/\sigma x^2$$

Where α = coefficient alpha, k = number of items, σi^2= the variance of item *i* and σx^2 = total test variance. Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the "underlying construct". Cronbach's alpha values of 0.7 to 0.8 are regarded as satisfactory (Taber, 2018). The construct for this study was perception concerning the influence of the 4 mechanisms of access and 6 conditions of agency, while the response continuum was, 1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree.

4.5 Results

The key informants identified 13 conditions for agency and 7 mechanisms of access that were perceived to influence people's ability to benefit from aquatic resources (Fig. 4.4). Overall, fish availability and adequacy, financial access, market access, fishing technological access, decision-making dynamics, legal access, cultural norms, fish palatability attributes, fish preparation, preservation and cooking knowledge and consideration of fish as a healthy diet emerged as the ten most dominant (representing 85% of mentions, n = 5484 mentions). Out of these top ten, three were structural and relational mechanisms of access (33% of mentions, n = 1794 mentions), three were personal conversion factors (13%, n = 723 mentions), two were social conversion factors (16%, n = 894 mentions) while one each was environmental conversion factor (15%, n = 796 mentions) and rights-based access mechanism (9%, n = 472 mentions).

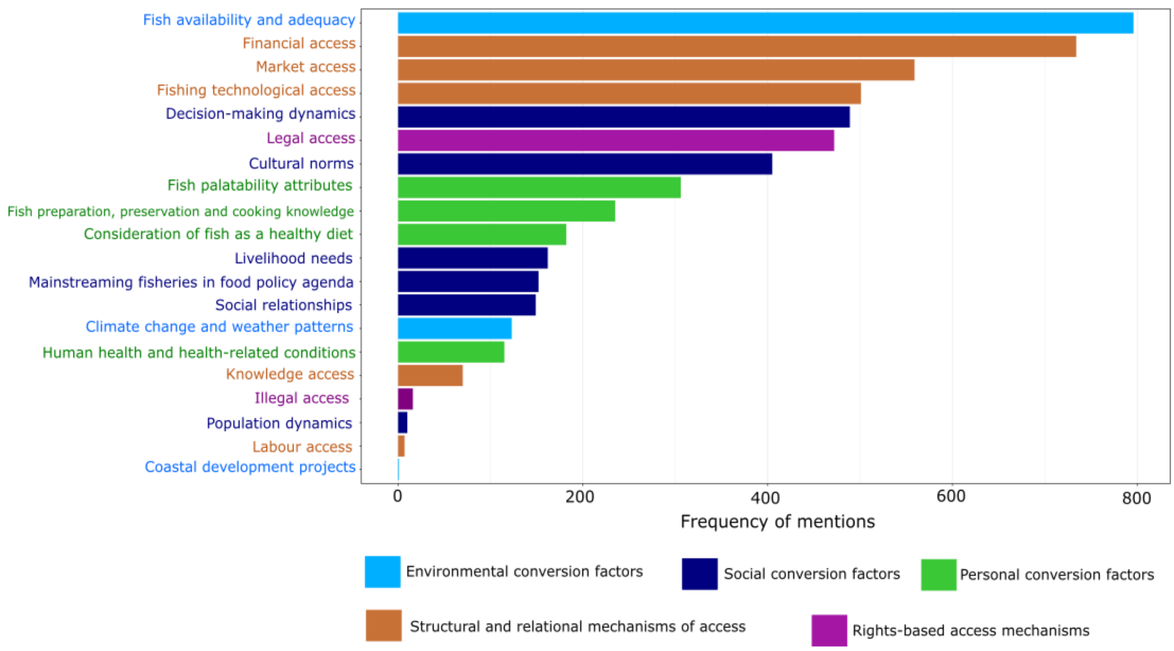


Figure 4.4 The 13 conditions for agency (light blue, deep blue and green bars) and 7 mechanisms of access (brown and purple bars) identified among the coastal communities of Kenya based on 116 key informant interviews

4.5.1 Conditions for agency

4.5.1.1 Environmental conversion factors

There were three environmental factors (1- fish availability and adequacy, 2- climate change and weather patterns, and 3- coastal development projects) that were perceived as conditions for agency (Fig. 4.5a). The main environmental factor mentioned was fish availability and adequacy in the ocean, which was framed as both enabling and constraining, with most mentions (62%, n = 495) framing this as an enabler and 38% (n = 301) framing fish unavailability and inadequacy as a constraint to obtaining fish for home consumption. Fish availability and adequacy was seen to positively influence agency by fish being readily available and adequate, the nearness of coastal and marine waters and high fish species diversity for consumption. However, it was framed as a constraint because of the changing availability (instability or seasonality) of fish, and scarcity or the associated inadequacy of fish (Table 4.3). Climate change and weather patterns, and coastal development projects were seen to constrain people’s agency to obtain fish. The key informants associated climate change with declines in fish catches, causing people to have to decide on whether to obtain fish for consumption by fishing harder or opt for other food alternatives. Coastal development projects were indicated as encroaching on fishing grounds or associated with causing physical pollution, thus influencing agency negatively as fish tend to migrate away from the affected fishing grounds forcing fishers to decide to find alternative fishing grounds.

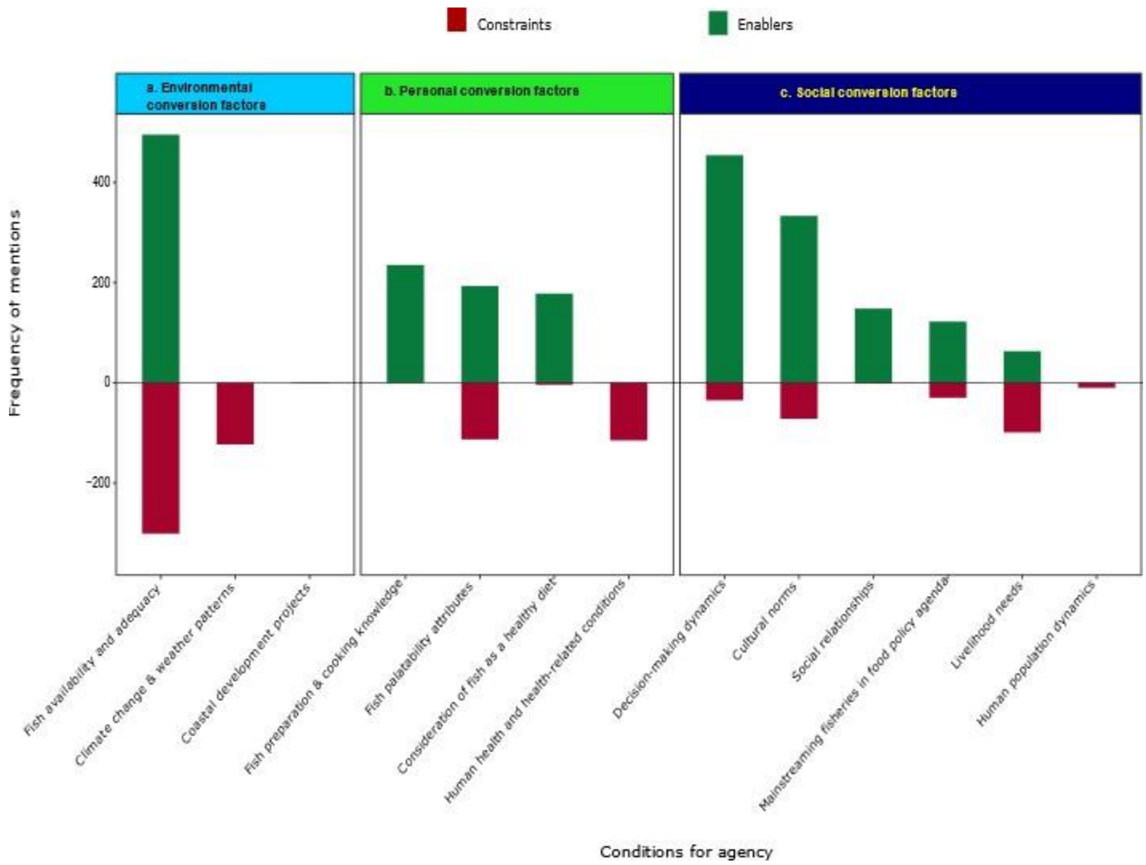


Figure 4.5 The 13 conditions of agency identified as a- Environmental conversion factors, b- Personal conversion factors, and c- Social conversion factors among the coastal communities of Kenya based on 116 key informant interviews and their influence on agency as enablers (green bars) or constraints (red bars)

4.5.1.2 Personal conversion factors

The coastal communities identified four personal factors as conditions for agency (Fig. 4.5b). Of these, fish preparation, preservation, and cooking knowledge were unanimously perceived as enabling agency (100%, n = 235) while human health and health-related conditions were considered as constraining (100%, n = 115). Fish palatability attributes were both enabling (63%, n = 193) and constraining (37%, n = 113) decisions about what fish to consume. Among the enabling fish palatability attributes were personal preferences of fish while constraints included dislike of how the fish smells, negative perceptions about how the fish tasted, negative perceptions about fish appearance, personal dislike of fish, poisonous nature of some fish, and poor edible quality of some fish (Table 4.3). Fish preparation, preservation, and cooking knowledge attributes included perceived ease of cooking and preparing fish, knowing about fish preparation, and cooking, knowledge about fish preservation, and the variety of fish cooking methods that may be used (Table 4.3). Human health and health-related conditions manifested in the form of allergic reactions and illnesses associated with eating some fish species thus being a constraint to decisions on consumption of such fish as well as shaping decision making about the choice of fish one would obtain for home consumption. The other aspect of health was physical body illness that caused fishers to decide not to go fishing, thus impacting the availability of fish.

4.5.1.3 Social conversion factors

Six social factors were identified as influencing agency (Fig. 4.5c). Decision-making dynamics were most frequently mentioned as enablers of agency (93%, n = 454) with only 7% (n = 35) of the mentions framing it as a constraint. This was followed by cultural norms, whereby 82% (n = 333) of the mentions identified the enabling influence of culture on agency while 18% (n = 72) indicated the constraining influence of culture. In their account of the social conversion factors influencing agency, the key informants frequently mentioned decision-making dynamics, cultural norms, social relationships, and mainstreaming fisheries in the food policy agenda as being positive while the priority to meet other livelihood needs, and population dynamics were framed as constraints for decisions to obtain fish for home consumption. Among the enabling aspects surrounding decision-making dynamics were household and individual prioritization of fish for consumption, household caregiver decision-making, household head decision-making, household members' decision for fish consumption, individual decisions to buy fish, individual decisions to fish, and community decision-making on obtaining fish for consumption (see Table 4.3 for some selected respondent narratives).

4.5.2 Mechanisms of access

4.5.2.1 Rights-based access mechanisms

This study revealed two rights-based mechanisms of access (Fig. 4.6a). While accounting for legal access and how it influenced access to fish for consumption, 96% (n = 453 mentions) held the opinion that the existing legal regulatory requirements were meant to facilitate access to fishing. However, 4% (n = 19) of the responses attributed regulatory requirements as a constraint to access. There was unanimity (100%, n = 16) that illegal access negatively influenced access. The enabling aspects of legal access included facilitative co-management and government regulatory decisions, requirements, and services (Table 4.3). On the other hand, constraining aspects were cited as restrictive fishing gear regulations, species restrictions and negative impacts of foreign or industrial fleets on local fish supply. Illegal access was associated with fishing conflicts (among fishers and between fishers and enforcement agencies) and illegal fishing methods that featured as constraining access.

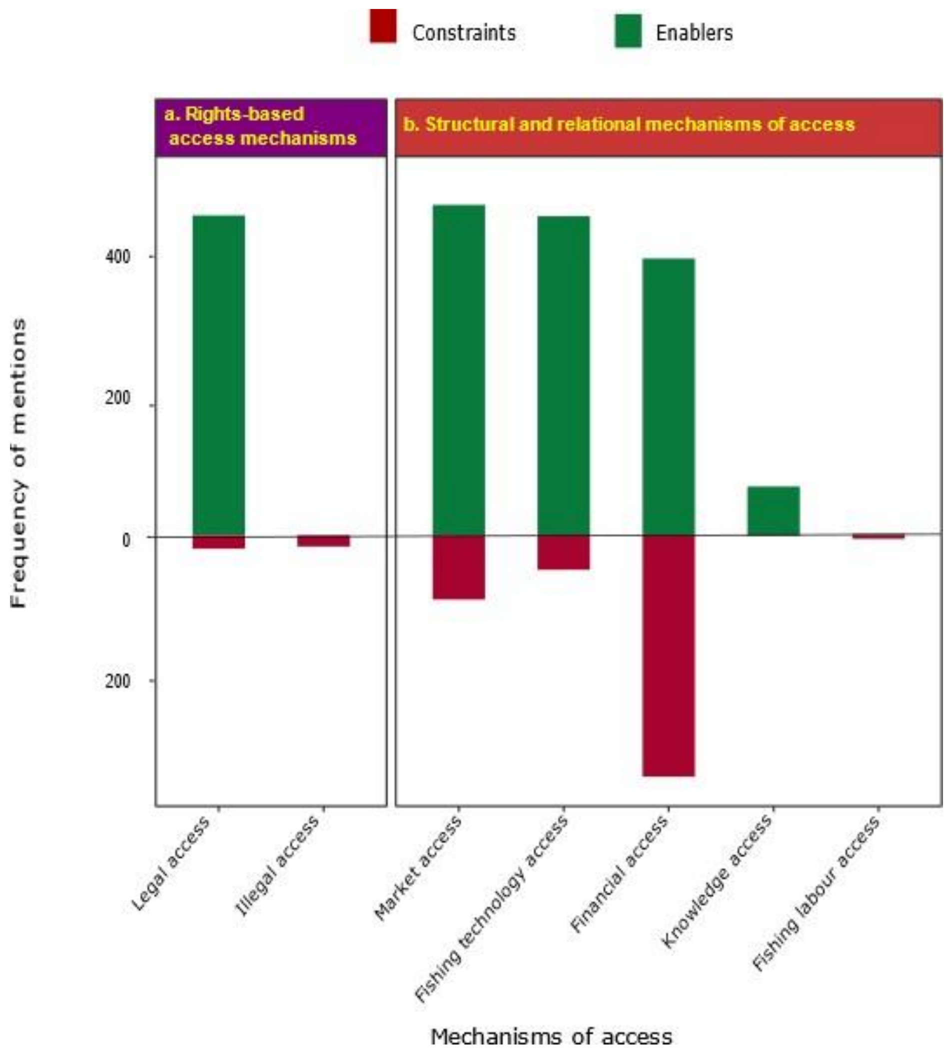


Figure 4.6 The 7 mechanisms of access identified as a- Rights-based access mechanisms, and b- Structural and relational mechanisms of access among the coastal communities of Kenya based on 116 key informant interviews and their influence on access as enablers (green bars) or constraints (red bars)

4.5.2.2 Structural and relational mechanisms of access

Findings showed five structural and relational mechanisms of access (Fig. 4.6b). Financial access was the most frequently mentioned mechanism of access with the key informants attributing financial adequacy at 53% (n = 392) and inadequate financial access at 47% (n = 342). Access to fish markets and fishing technologies were indicated as enablers by 84% (n = 468) and 90% (n = 452) of mentions respectively. On the contrary, 16% (n = 91) and 10% (n = 49) of the mentions highlighted market access and fishing technology access as constraints respectively. Knowledge access about fishing technology, markets, and legal requirements was considered mainly as an enabler (99%, n = 69) rather than a constraint (1%, n = 1) while labor access was mainly indicated as a constraint (71%, n = 5) than enabler (29%, n = 2). Financial access was reflected in key informants' accounts as positive contributors to access through the ability to buy desired fish and having money to buy fish but as a hindrance through fish being considered as a source of income (whereby individuals preferred to sell the fish for money rather than take it home for consumption), and monetary inadequacy. Narratives in support of market access as an enabler included the existence of different market types, proximity to the market, and ready availability of fish at the markets (Table 4.3) while responses to the effect that the market was a constraint indicated high market demand for fish away from the village that led to fish being exported to peri-urban and urban town settlements, leaving the village devoid of fish.

Table 4.3 Summarized themes and related sub-themes that emerged from key informants' responses to identifying mechanisms of access and conditions for agency and selected sample statements from the key informants. These are grouped under five thematic dimensions based on a Theory of Access (Ribot and Peluso, 2003) and Capability Approach (Nussbaum and Sen, 1993; Nussbaum, 2013)

Thematic dimensions	**Sub-thematic components**	**Selected example respondent statements from which the themes and subthemes were derived (translated from Kiswahili to English)**
Environmental conversion factors	Fish availability and adequacy	1. It is uncertain how much fish I can consume daily because fish catches vary throughout the year. Therefore, my fish consumption is higher when catches are high and lower when catches are low (fifonuse-ke respondent15mjk - 210317_001). 2. Fish is not consistently adequate, but catches fluctuate, today you may get 20 kg but tomorrow you get nothing. Fish catches vary with seasons, for example December to March we get something, February to June we also get but July to September there is a lot of scarcity of fish (Interviewee 17wn-mjk_210318_002).
Personal conversion factors	Fish palatability attributes	3. Some fish do not taste nice (for example "vumbama" i.e., crocodile fish) or have sandy texture such as "kangaja" i.e., surgeonfish, thus making them unpalatable for home consumption and some are very tasty such as "ngisi", "tasi" and "changu" (fifonuse-ke-respondent17kby - 210414_003). 4. There are some types of fish that I just don't like such as eels and those with very hard flesh and smell after cooking such as "kinuka" and others such as "mashoto" which have no taste (fifonuse-ke-respondent2shm - 210329_002).
	Fish preparation, preservation, and cooking knowledge	5. Once I get the fresh fish, I begin by descaling and removal of internal organs, then I wash thoroughly and depending on species and preferred cooking method such as boiling, or frying I cook it (fifonuse-ke-respondent14shm - 210402_003). 6. On fish preparation, I wash, descale, dissect, and remove internal organs, then wash again, then I slice it, add necessary ingredients such as masala and pepper, then deep fry. For boiling, add some little salt and lemon or unripe mango or tamarind (fifonuse-ke-respondent18kby - 210416_001).
	Consideration of fish as a healthy diet	7. Fish is important for my health since it adds essential fats, improves blood levels, builds body energy, and maintains general body health (fifonuse-ke-respondent18kby - 210416_001). 8. Fish is the most commonly available protein source in this village, consumed by many people sometimes during the morning, noontime, and evening mealtimes (interviewee6pk -shm_210331_003).

Thematic dimensions	Sub-thematic components	Selected example respondent statements from which the themes and subthemes were derived (translated from Kiswahili to English)
Social conversion factors	Cultural norms	9. Seventh Day Adventists prohibit consumption of fish that do not have scales (fifonuse-ke-respondent21shm - 210406_002). 10. There is a fish called "fufu" that women were not supposed to eat the tail end, but our investigations revealed that it is actually the tail end that has more flesh, but such beliefs are no longer being implemented (fifonuse-ke-respondent2shm - 210329_002). 11. Mostly people here eat almost all types of fish some may even surprise you, they believe octopus offers important energy for men and breastfeeding mothers (interviewee6pk -shm_210331_003). Here we eat all types of fish because God says that all fish and seafood is "halal" except those that are poisonous and harmful to health (Interviewee 9sz-kby-210412_002).
	Decision-making dynamics	12. When it comes to fish consumption in my house, I am the one as the household head and provider who decides whish species and quantity of fish we will eat and which to sell (fifonuse-ke respondent10mjk - 210313_003). 13. I make daily decisions about going fishing while my wife goes farming and upon fishing, I decide how much to take home for consumption but after agreement with my fishing partner on what to set aside for selling to get cash and home consumption - "kitoweo" (interviewee 9mm- shm - 210401_004).
	Mainstreaming fisheries in food policy agenda	14. The way we live here is that in times of plenty, fishers get to save some money which they can then use to buy food thus mainstreaming fisheries and food policies this way helps us (fifonuse-ke respodent 11Kby- 210411_003). 15. Fish is administered by the fisheries department and general food is by the agricultural department although both fall under same ministry but should be governed separately even though marine fisheries production has not been given much emphasis in Kenya (Interviewee 4rh-shm_210331_001).
	Livelihood needs	16. Normally, I sell fish that I catch to get money for food, family support, school fees, clothing and eat part of it (fifonuse-ke respondent15mjk - 210317_001). 17. There are some fish such as prawns and lobsters that we can eat and are highly nutritious but considering their economic value and domestic needs in the household, we would rather not eat such expensive fish but sell them and get the money to meet other needs that we have (fifonuse-ke respondent10mjk - 210313_003).
Rights based access mechanisms	Legal access	18. There are access requirements nowadays that include having a fishing license, being a beach management unit (BMU) registered member, not having illegal gears such as small-meshed nets, monofilaments and spearguns (fifonuse-ke respodent16 shm - 210404_002). 19. For formalization of fisheries activities and monitoring, control and surveillance, fishers are expected to meet stipulated legal regulations from different acts such as having valid fishing license, having fishing vessels registered and clearly marked with registration number, use of non-destructive fishing gears and adherence to not using illegal fishing gears such as beach seines, dynamiting, poisonous substances, monofilaments and spearguns (Interviewee 22co-shm-210408_001).
Structural and relational	Financial access	20. When I have money, I can buy fish even when my husband hasn’t fished and brought fish home (fifonuse-ke respodent 11kby- 210411_003).

Thematic dimensions	Sub-thematic components	Selected example respondent statements from which the themes and subthemes were derived (translated from Kiswahili to English)
mechanisms of access		21. One of the challenges I face during fish scarcity is lack of money to buy fish and not being able to go fishing (fifonuse-ke respondent11mjk - 210315_001). 22. The fish I obtain for home consumption is dependent on my income/money thus it is adequate when I have more money and inadequate when I have less money to buy (fifonuse-ke-respondent3kby - 210409_001).
	Fishing technological access	23. Having the right fishing gears enables me to go out fishing (fifonuse-ke respodent16 shm - 210404_002). 24. We get fish using different fishing gears such as traps, handlines, gillnets, and vessels (Interviewee 9sz-kby-210412_002). 25. Lack of appropriate fishing equipment and gears restricts access to offshore fishing grounds which are presumably richer in fish than the overfished inshore habitats (Interviewee 22co-shm-210408_001).
	Market access	26. Most of the fish we get here are sold in the nearby urban centres such as Ukunda, especially large size or grade but small ones are sold locally to female fish friers for the village market (interviewee15or-shm-210405_001). 27. The fish we catch here is mainly sold out to dealers who take it to Mombasa if they are large but most of the small grade is sold locally to female fish traders who trade within this village (fifonuse-ke respodent14kibuyu - 210412_003). 28. Our village market here enables my accessing fish since it is near, fish prices are fair, there are fishers I know go fishing daily and can sell fish to me cheaply (fifonuse-ke respondent11mjk - 210315_001).

4.5.3 Household respondents' perceptions survey

The analysis of the household survey Likert-scale data for the 4 mechanisms of access and 6 conditions of agency that were dominant resulted in Cronbach's Alpha value α = 0.70 (interpreted as acceptable). The findings indicate that among the mechanisms of access, financial access was perceived to be more important with a mean of 4.94±0.36 while legal access was the lowest with a mean of 4.59±0.90 (Table 4). Among the conditions for agency, it was found that fish preparation, preservation, and cooking knowledge was the most important with a mean of 4.98±0.18 while decision-making dynamics was the lowest with a mean of 4.77±0.64 (Table 4.4).

Table 4.4 Item statistics on household respondents' perceptions of the 4 mechanisms of access and 6 conditions of agency, n = 547, SD = standard deviation

Mechanisms of access	**Mean**	**SD**
Financial access	4.94	0.36
Market access	4.84	0.64
Fishing technological access	4.82	0.68
Legal access	4.59	0.90
Conditions of agency		
Fish availability and adequacy	4.92	0.47
Decision-making dynamics	4.77	0.64
Cultural norms	4.93	0.44
Fish palatability attributes	4.90	0.42
Fish preparation, preservation, and cooking knowledge	4.98	0.18
Consideration of fish as a healthy diet	4.96	0.23

Overall, it was found that over 90% of the participants strongly agreed that knowledge about fish preparation, preservation, and cooking was important for their decision-making about fish consumption within households, followed by consideration of fish as a healthy diet while 75 - 85% of respondents reported lower strong agreement with legal access and decision-making dynamics (Fig. 4.7).

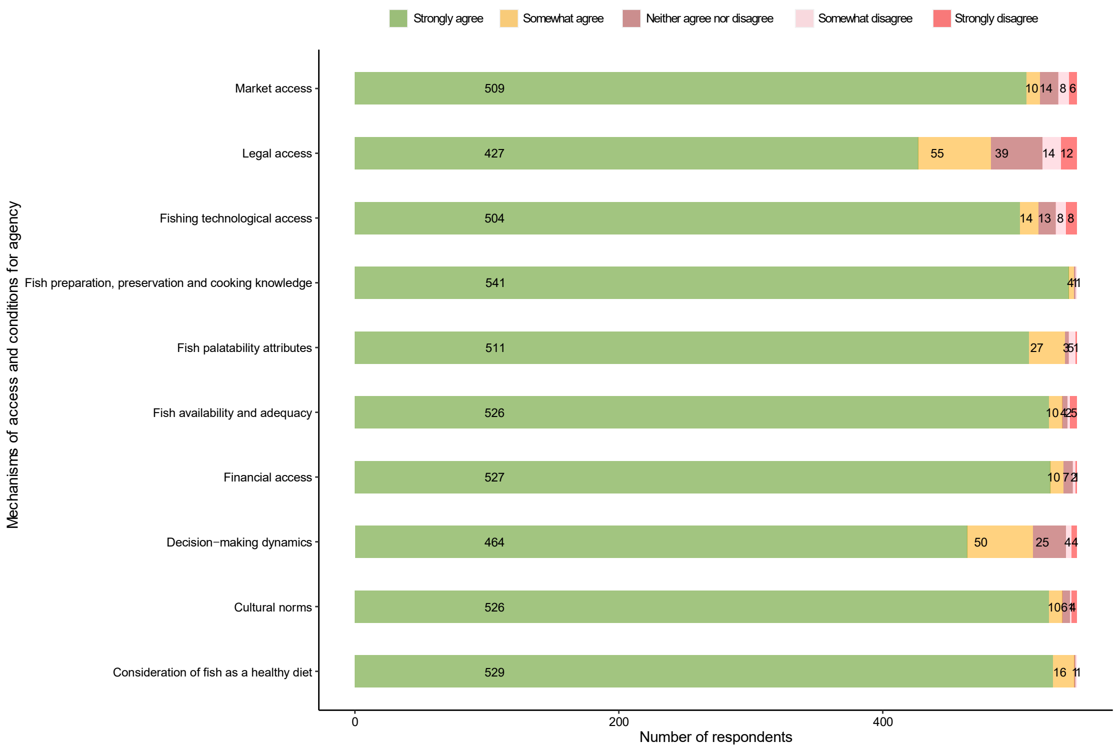


Figure 4.7 Household respondents' perceptions of the 4 mechanisms of access and 6 conditions for agency that were dominant from the analysis of key informant interviews (n= 547)

4.6 Discussion

Findings in this chapter identified the mechanisms of access and conditions for agency that were most likely to shape people's ability to benefit from aquatic resources, and thus support food and nutritional security in coastal Kenya. This forms an empirical basis and understanding upon which to reflect on how tropical fish food systems governance support processes to facilitate more equitable access to fisheries resources for all. There are high incidences of diets that lack essential micronutrients in Kenya (Downs *et al.*, 2022) with coastal counties featuring among affected communities (Lokuruka, 2020; Momanyi *et al.*, 2019; Kamau-Mbuthia *et al.*, 2023) yet they are close to nutrient-dense fisheries resources that can help alleviate nutritional deficiencies. Therefore, I discuss the conditions for agency and mechanisms of access as revealed under the five themes: 1. environmental conversion factors, 2. personal conversion factors, 3. social conversion factors, 4. rights-based access mechanisms, and 5. structural and relational mechanisms of access and then synthesize how these may enable or constrain people's abilities to obtain fish for food and nutrition goals.

4.6.1 Conditions for agency

4.6.1.1 Environmental conversion factors

Among the environmental factors identified as influencing agency, changing climate and weather patterns, availability of fish, including species diversity of consumable fish, were important in shaping fish availability and adequacy. Availability and adequacy of food supplies are key drivers of food consumption (Govzman *et al.*, 2021; Monterrosa *et al.*, 2020; Carlucci *et al.*, 2015; HLPE, 2020). I identified perceived declines of fisheries resources from the ecosystems as a deterrent to the human development agenda (Cinner *et al.*, 2012; Martinez-Juarez *et al.*, 2015; McClanahan *et al.*, 2015; Pattanayak *et al.*, 2017) due to its association with limiting decision-making about obtaining fish for consumption. Yet decision-making about harnessing food systems such as fisheries resources is a key dimension of food and nutrition security. Fish availability and adequacy are dependent on other environmental factors (Cheung *et al.*, 2021; Cinner *et al.*, 2012, 2012; Maire *et al.*, 2021) including climate change and daily weather changes that influence agency (Ferguson *et al.*, 2022). The presence of a high diversity of edible fish species from marine ecosystems provides people with diverse preferences of fish to choose from. Factors found to determine fish consumption include individual preferences and the presence of favorable fish species (Lee and Nam, 2019; Downs *et al.*, 2022; Harris-Fry *et al.*, 2017; Issifu *et al.*, 2022). Therefore, the presence of high species diversity of consumable fish in marine and coastal ecosystems offers the opportunity to meet multiple consumer tastes and preferences thus promoting agency (Kilpatrick *et al.*, 2017; Bernhardt and O'Connor, 2021).

4.6.1.2 Personal conversion factors

The positive perceptions of fish as nutritious form of food in people's diets, signified the recognition of fish as a nutritious super-food in this coastal context (Hicks *et al.*, 2019; Kawarazuka and Béné, 2011; Maire *et al.*, 2021; Robinson *et al.*, 2022b). Consumer choices of food for consumption have indicated considerations of health benefits of particular food items as drivers of choice

(Carlucci *et al.*, 2015; Cantillo *et al.*, 2021; Ghosh-Jerath *et al.*, 2021; Harris-Fry *et al.*, 2017). The negative implications on health manifested from eating fish that are associated with causing allergic reactions and other health risks (e.g. rabbitfish, sharks, shrimps, and crabs), hampered decisions for their uptake for nutrition (Carlucci *et al.*, 2015). Personal preferences have been found to impact food consumption at both the individual and household levels (Downs *et al.*, 2022; Harris-Fry *et al.*, 2017). Knowledge about food preparation, preservation, and cooking has been noted to promote the consumption of individual foods, including fish (Ghosh-Jerath *et al.*, 2021; Govzman *et al.*, 2021). Additionally, as a capability, knowledge of fish preparation, preservation, and cooking enables decision-making on access and use of fish for consumption, thus contributing to food and nutrition security. The influence of palatability attributes has been expressed through the sensory appeal of food (sensory liking or disliking of fish), taste, smell, or even appearance (Karanja *et al.*, 2022; Carlucci *et al.*, 2015; Cantillo *et al.*, 2021; Ghosh-Jerath *et al.*, 2021).

4.6.1.3 Social conversion factors

Decision-making dynamics at the individual, family, and community levels appear to play a bigger role in influencing people's agency to obtain fish for consumption. Decision-making dynamics surrounding food consumption in households are key to meeting nutrition needs (Downs *et al.*, 2022; Karanja *et al.*, 2022). Most of the decision-making processes were positive for the uptake of fish for consumption. However, when the consumption of some fish is either disliked by a member or is associated with some allergy or illness or is considered culturally prohibited, this results in decisions that hamper fish uptake. Other social conversion factors such as cultural norms, social/interpersonal relationships, other livelihood needs, and population dynamics (size of family) have been found to influence food consumption decision-making (Downs *et al.*, 2022; Harris-Fry *et al.*, 2017; Carlucci *et al.*, 2015; Issifu *et al.*, 2022; Govzman *et al.*, 2021; Karanja *et al.*, 2022). The influence of culture, prioritization of other household needs, population size, food safety, and health concerns have been implicated in nutritional outcomes and general food security (Carlucci *et al.*, 2015; Downs *et al.*, 2022; Issifu *et al.*, 2022; Karanja *et al.*, 2022). Therefore, enhancing agency in harnessing fisheries resources for improved nutritional health outcomes calls for the consideration of these social conversion factors in the context of their occurrence.

4.6.2 Mechanisms of access

4.6.2.1 Structural and relational mechanisms of access

Under the structural and relational mechanisms of access, I identified financial ability, market access, and fishing technology as important means for the achievement of access to fish for home consumption in these coastal communities. Associated with the financial access were household income status, financial allocations to other needs, and the price of fish (Lee and Nam, 2019; Downs *et al.*, 2022; Harris-Fry *et al.*, 2017). Some people compared the price of fish with that of other substitutable animal-sourced foods, opting for the latter when fish prices were high. Perceptions of high fish prices reflect on cost and affordability of fish as a healthy diet (Herforth *et al.*, 2020; Govzman *et al.*, 2021; Issifu *et al.*, 2022) while some studies associate household members' income and wealth (Harris-Fry *et al.*, 2017) as drivers of access. The influence of income and prices on the choice of food to be eaten has been identified (Downs *et al.*, 2022; Lee and Nam, 2019).

The influence of markets on fish availability and access is important for the attainment of food and nutrition security (Maire *et al.*, 2020; Milner *et al.*, 2022). Fishing technology manifested in the form of having the appropriate fishing gears, vessels, and associated inputs and the presence of cold storage infrastructure as enablers while the lack of these was considered a deterrent to access. The importance of fisheries infrastructure to support food and nutrition security cannot be overlooked (Fauconnet *et al.*, 2015; Omukoto *et al.*, 2018). Knowledge access about structural and relational mechanisms included knowledge about fishing technologies, markets, and finance options. Labor access was indicated as a constraint where lack of or absence of a fishing partner would limit going fishing while the presence of migrant fishers was considered an enabler to fish dealers who employ them for fishing operations. Migrant fishers have been found to play a key role in fishing activities in Kenya (Fulanda *et al.*, 2009; Wanyonyi *et al.*, 2016), and therefore their presence seems to enable access to fishing grounds that may not be reachable by local fishers.

4.6.2.2 Rights-based access mechanisms

The existence of legal and illegal access featured as rights-based access mechanisms because these two are sanctioned by law, custom, or convention with illegal access included since it defines situations where benefits are obtained through illegal mechanisms (Ribot and Peluso, 2003). The importance of managing small-scale fisheries cannot be ignored (FAO, 2015; Chuenpagdee and Jentoft, 2019; McConney *et al.*, 2019; McClanahan *et al.*, 2015; Aguión *et al.*, 2022; Purcell and Pomeroy, 2015). The two-level co-management arrangements in Kenya's small-scale fisheries (i.e., beach management units' and the government's regulatory decisions, requirements, and services) were the main enablers of access to the fishery. Fisheries resources in Kenya are governed by multiple institutions with regulations cutting across them. However, the Fisheries Management and Development Act of 2016 is the main legislation providing for access to fishing. There are several regulatory requirements that one has to meet to be able to gain access to the fishery (Tuda *et al.*, 2023). Meeting those regulations was therefore considered an enabler of access while for those who were not able to meet the regulations due to some reasons, such requirements were considered prohibitive to access, hence a constraint to obtaining fish. Incidences of fishing communities considering strict fisheries legislations and policies as prohibitive have been reported (Freduah *et al.*, 2017). However, the need to govern fisheries operations to ensure fisheries sustainability and responsible production beckons (Aguión *et al.*, 2022; FAO, 2015; HLPE, 2014) in order to safeguard nutrient gains from fish food systems. This is crucial considering that for countries to meet their aquatic food demand and contribute to global blue food demand, good governance that is cognizant of both environmental and nutritional consequences of ocean mismanagement ought to be in place (Naylor *et al.*, 2021).

4.6.3 Household respondents' perceptions of the 4 mechanisms of access and 6 conditions for agency

The concurrence of the perceived importance of the main mechanisms of access and conditions for agency by both the household respondents and the key informants underscores their importance of ensuring agency and access

(Monterrosa *et al.*, 2020; Govzman *et al.*, 2021; Green *et al.*, 2021; Karanja *et al.*, 2022). Considering that all respondents who participated in the household surveys were women reflects the lower agreement on legal access and decision-making dynamics to some degree. This may be attributed to the fact that women have been associated with lower involvement in decision-making and fishing activities despite their engagement in most fisheries postharvest (Galappaththi *et al.*, 2022; Nunan and Cepić, 2020). In my assessment, their involvement in obtaining fish for food was appraised in knowledge about preparation, caregiver decision-making, and health considerations that are important in the utilization of fish in households (Govzman *et al.*, 2021; Issifu *et al.*, 2022).

4.6.4 Synthesis of the emergent mechanisms of access and conditions for agency

Overall, this study shows that an interplay of power dynamics (mechanisms of access), and social, personal, and environmental factors (conditions for agency) shape access and agency for fisheries-based nutritional health outcomes in coastal communities. An understanding and consideration of the revealed mechanisms of access and conditions for agency enlighten the evaluation of social inclusion and fairness since they reveal the actual experiences of people and their agency, their daily realities in making decisions, and accessing fish for nutrition security. The mechanisms of access and conditions for agency may influence the opportunities and choices at the individual and community micro-level. The influences of social, institutional, and knowledge mechanisms have been associated with diverse benefits (Hicks and Cinner, 2014). The achievement of access and agency toward ensuring food sovereignty at the community scale requires considerations of culture, knowledge systems, labour practices, and ecosystem dynamics (Ferguson *et al.*, 2022). An understanding of how the revealed mechanisms of access and conditions for agency enable or constrain access and agency forms a useful basis for facilitating adaptive capacity in coastal communities (D'agata *et al.*, 2020). Further, this would help develop appropriate interventions that support fish food systems to be consistent with the identified social processes and power dynamics within the coastal communities.

4.7 Conclusions and policy implications

4.7.1 Conclusions

This study was conceptualized based on the understanding that people have different levels of access to fisheries resources and make varied decisions concerning obtaining fish for their consumption influenced by different factors, and hence the presence of inequalities. Consequently, I identified the need to unravel the mechanisms of access and conditions for agency to help address the current course of disparities and support the achievement of nutrition security for the most vulnerable. I established that people's access to fish and their decision-making (agency) about obtaining fish for consumption and being involved in policy and management processes concerning the fishery resources were influenced by multiple mechanisms of access and conditions for agency. The 7 mechanisms of access and 13 conditions for agency that I found emerged as rather complex due to the intricate linkage between access and agency and how these influenced ways and decisions of obtaining fish for home use. The study sheds light on these mechanisms of access and conditions for agency that are existent and proposes that they be used as entry points to leverage the transformation of small-scale fisheries governance and policy frameworks by relevant practitioners and policymakers.

4.7.2 Policy implications

This study reveals that the realization of food and nutrition security commitments through the consumption of fish would require leveraging upon the mechanisms of access and conditions for agency drawn from Fig. 4.1. Therefore, policy interventions geared towards enhancing nutritional outcomes need to promote enablers, circumvent or tackle constraints, and prioritize contextual determinants. The research findings affirm 7 mechanisms of access and 13 conditions for agency that I highlight as potential entry points to leverage policy, inform intervention efforts for management, and shape changes towards enhancing access to fish and transforming decision-making about fish preferences, choice, and consumption. I point out the need for a "situated fish for food and nutrition action" i.e., a local action in the fish for nutrition agenda that promotes the peoples' capabilities to develop their rights, freedoms, and chances to have access to the fisheries resources to achieve their livelihood aspirations. Incorporating the identified mechanisms of access and conditions for agency will promote steps towards solving observable inequalities across social, political, and economic environments within which the communities live. This is important because policies that fail to consider such underlying social processes and power dynamics - no matter how practical, technical, or scalable - are prone to fail (Hossain, 2017).

In a nutshell, safeguarding the mechanisms of access and conditions for agency that promote the gains of obtaining fish for food and nutrition security is recommended. This could include building capabilities through promoting enablers, and circumventing, or overcoming the constraints as key policy interventions for improving access and agency to fish for food and nutrition security. Further research to explore the effectiveness of specific interventions that may be aimed at increasing access and expanding agency about the consumption of fish for better nutritional outcomes in coastal communities is recommended.

Chapter 5. Fish consumption and household sociodemographic factors impact human health outcomes: evidence from coastal fishery-adjacent communities in Kenya

5.1 Abstract

I previously identified factors that influence the availability (Chapters 2 and 3), access (Chapters 3 and 4), and agency (Chapter 4) pillars of food security in coastal Kenya, and proposed policy interventions with implications for stability and sustainability. Factors associated with the utilization pillar are yet to be assessed. Therefore, in this chapter, I used dietary diversity, dietary patterns, and food insecurity as indicators of the utilization pillar, because they are directly linked to human health outcomes. Here, I address an under-assessed area of food security and nutrition and examine how household fish consumption and sociodemographic factors, influence dietary diversity, dietary patterns, and food insecurity in coastal Kenya. I use cross-sectional household survey data, (introduced in Chapter 4) gathered from 547 participants across three villages, and use generalized linear models, to analyze the relationships. Households that consumed fish more days per week, had access to modern sanitation facilities, and adequate drinking water supply reported higher levels of dietary diversity. The most diverse dietary patterns were associated with the highest frequency of weekly fish consumption. Severe food insecurity (33.6%) and moderate or severe food insecurity (90.7%) were higher in the coastal villages than the global and national averages. Households with higher levels of formal education (post-primary), who were involved in fisheries production, food-related business, engaged in formal employment, consumed more fish, or had access to modern sanitation facilities, were less likely to be food insecure. Overall, the fish food system contributed directly to dietary diversity, dietary patterns, and food security by providing essential food items (seafood) and indirectly to food security as a livelihood resource (employment). These findings have significant policy implications for interventions aiming to support fish food system transformations to achieve food and nutrition security in coastal communities. These interventions could include a focus on improving employability, access to education, and facilitating fish availability, access, and decision-making related to healthy dietary

patterns as integral components of the food system especially for those with lower socioeconomic status, and lower levels of education.

In preparation - Omukoto JO, Graham NAJ, Thorne-Lyman A, Hicks CC. Fish consumption and household sociodemographic factors impact human health outcomes: evidence from coastal fishery-adjacent communities in Kenya. *Frontiers in Sustainable Food Systems Journal*

5.2 Introduction

The global rise in hunger and severe food insecurity reveals growing inequalities in the delivery of nutritious, safe, and affordable diets due to a variety of factors among the affected people across and within nations (FAO, IFAD, UNICEF, WFP and WHO, 2023). The primary factors endangering food and nutrition security are complex, constantly evolving, and persistently pose developmental challenges (FAO, 2020; FAO, IFAD, UNICEF, WFP and WHO, 2022; FAO, 2021). Overall, current global challenges to food and nutrition security include high food prices, COVID-19 disruptions, limited access to resources, conflict and instability such as the Russia-Ukraine war, urbanization and changing diets, and extreme climatic conditions (FAO, IFAD, UNICEF, WFP and WHO, 2022; Mehrabi *et al.*, 2022; Vila-Real *et al.*, 2022; World Food Programme, 2020).

Addressing the challenge of food and nutrition security has been focused on transforming terrestrial food production systems, with the considerable potential of aquatic systems to deliver food security benefits being less appreciated (Tigchelaar *et al.*, 2022; Crona *et al.*, 2023; Thilsted *et al.*, 2016; HLPE, 2014). Yet, in many countries, fish provide a readily available and cheap source of protein and are particularly high in micronutrients (Golden *et al.*, 2016, 2021; Kawarazuka and Béné, 2011; Robinson *et al.*, 2022c). Indeed, fish consumption has been linked to beneficial health outcomes such as decreased heart disease, gastrointestinal cancer, metabolic syndrome, and dementia (Li *et al.*, 2020; Marinac Pupavac *et al.*, 2022), low heart failure (Mahdavi-Roshan *et al.*, 2021), decreased risk of all-cause mortality (Qu *et al.*, 2022), and general better health (Li *et al.*, 2020). Therefore, small-scale fisheries, which involve 90% of the world's fishers - over 300 million people - predominantly in low-income countries (Mills *et* *al.*, 2011), hold considerable potential to address gaps in global food and nutrition security. However, small-scale fisheries remain a 'forgotten food' in the global food security discourse (FAO, 2022b; Béné *et al.*, 2015) with calls to consider this sector in food policy strategies mounting (Cohen *et al.*, 2019). Fish and fishery products are significant for the livelihoods, food security, and nutrition of billions of people around the world but lack consistent policy support indicators (FAO, IFAD, UNICEF, WFP and WHO, 2022). There are growing interventions amplifying the importance of fish to nourish people, particularly those in rural and other marginalized communities that are adjacent to fishery resources (Adesina, 2022; Hicks *et al.*, 2021). This follows the understanding that fish is crucial for rural populations, who often have less diverse dietary sources and lower food security rates (Thompson and Amoroso, 2014).

Dietary diversity refers to the number of food groups consumed by a household or an individual over a reference recall time such as 24 hours, 3 days, or 7 days (Alnafissa, 2016; Hoddinott and Yohannes, 2002; Harper *et al.*, 2022; Ruel, 2003). Dietary diversity scales are of interest as some have been validated against measures of nutrient adequacy while others have been associated with caloric intake (Moursi *et al.*, 2008; Verger *et al.*, 2021). A higher dietary diversity score indicates better diversified dietary patterns and hence adequate consumption of essential nutrients (Qu *et al.*, 2022; Heidkamp *et al.*, 2020; Working Group on Infant and Young Child Feeding Indicators, 2007). Dietary diversity data can be rapidly collected making it feasible to integrate indicators of diet into large-scale surveys (Food Research & Action Center, 2017; Fadnes *et al.*, 2022; Cena and Calder, 2020). Poor dietary diversity, inadequate dietary patterns, and frequent consumption of foods of high energy density and less nutritional value have been linked to malnutrition and non-communicable diseases in later life (Fang and Gurinović, 2023). Examining dietary patterns offers the advantage that it considers the complex interrelations between different foods that reflect actual dietary habits (Kelly *et al.*, 2018; Zhao *et al.*, 2021). Dietary patterns have also been found to be more consistent over time and shown to have a greater effect on health outcomes than individual nutrients (Schulze *et al.*, 2018; Boateng *et al.*, 2019). Food insecurity refers to the situation where there is constrained or unreliable availability of nutritionally adequate and safe foods, or the limited or uncertain ability to acquire sufficient, safe and nutritious food, which meets the dietary needs and food preferences for an active and healthy life (FAO, IFAD, UNICEF, WFP and WHO, 2022; Beyene, 2023). Food insecurity has been shown to contribute to poor health and nutritional outcomes (Mohamadpour *et al.*, 2012). Food security is a pathway toward securing good nutritional outcomes (Tiwari *et al.*, 2013), thus measures or indicators of food security that carry valuable hints about the nutritional status of the targeted population have high policy relevance for improved nutrition (Tiwari *et al.*, 2013).

Achieving high dietary diversity, healthy dietary patterns, and overcoming food insecurity at the household level depends on different sociodemographic factors that need to be accounted for when intervening for food and nutrition improvements. Several socio-demographics have been linked to dietary diversity and food insecurity (Grimaccia and Naccarato, 2019; Sargisson *et al.*, 2020; Ebrahimi *et al.*, 2023). Individual attributes such as gender, age, education, and household characteristics such as the number of people in the household and location of the household have been associated with changes in dietary diversity and food insecurity (Dudek and Myszkowska-Ryciak, 2020; Chalermsri *et al.*, 2022). Research recommends addressing such social determinants of health to improve health and reduce inequities in health (Braveman and Gottlieb, 2014; Commission on Social Determinants of Health, 2008). Dietary diversity, dietary patterns, and food insecurity have been directly linked to human health outcomes (Mahdavi-Roshan *et al.*, 2021; Bandyopadhyay *et al.*, 2021; Qu *et al.*, 2022; Mohamadpour *et al.*, 2012; Beyene, 2023; Food Research & Action Center, 2017; Hadley *et al.*, 2008; Mogeni and Ouma, 2022; Gassara and Chen, 2021; Harper *et al.*, 2022). However, how fish consumption and household sociodemographic factors impact dietary diversity, dietary patterns, and food insecurity for improved human health outcomes remains under-assessed in many contexts due to a lack of supporting data that can inform food and nutrition security interventions. Yet, most of the coastal communities, adjacent to nutritious aquatic food resource systems, are food insecure and characterized by poor dietary quality (O'Meara *et al.*, 2021; Kamau-Mbuthia *et al.*, 2023; Hicks *et al.*, 2019).

Improvements in diet quality in Sub-Saharan African countries remain challenging to date (Miller *et al.*, 2022). Therefore concern regarding food and nutrition security remains critical, with ongoing challenges that need to be addressed (FAO, IFAD, UNICEF, WFP and WHO, 2022; HLPE, 2020). The achievement of food and nutrition security in rural Sub-Saharan African coastal villages adjacent to nutritious aquatic foods requires an understanding of factors that influence dietary diversity, dietary patterns, and food insecurity to be able to support interventions and successful coping mechanisms. Knowledge and data gaps exist on how fish consumption and socio-demographics influence dietary patterns and food insecurity in communities that are known to be highly dependent on fish food systems in Kenya. Kenya is currently listed among low-income food-deficit countries and the number of people experiencing severe food insecurity more than doubled from 7 million in 2014-2016 to 14.8 million during 2020-2022 (FAO, IFAD, UNICEF, WFP and WHO, 2023). The Eastern Africa region generally, and Kenya particularly is characterized by inadequate fish supply and low levels of per capita fish consumption (Obiero *et al.*, 2019; Schubert *et al.*, 2021). However, coastal communities are highly reliant on marine aquatic foods as an essential component of their diets (Klaver and Mwadime, 1998). Coastal communities in Kenya are also reported to face severe droughts and hunger (Lokuruka, 2020).

While there have been acknowledgements that fish are important for food and nutrition security (Kamau-Mbuthia *et al.*, 2023; Fiorella *et al.*, 2014; Darling, 2014; Odoli *et al.*, 2019; FAO, 2022b), there has been a lack of supporting data and information to provide policy-relevant leverage for food and nutrition security among coastal fishery-adjacent communities. There is a need for empirical, quality, timely, and relevant data to inform actions that promote the availability, access, decision-making (agency), and utilization dimensions for improved food and nutrition security (HLPE, 2022). Therefore, I aimed to 1. Evaluate how fish consumption influences dietary diversity, dietary patterns, and food insecurity (as proxies of human health outcomes), and 2. Examine how the individual and household sociodemographic factors were associated with dietary diversity, dietary patterns, and food insecurity. The study provides empirical evidence useful to relevant decision-makers, and practitioners charged with mainstreaming small-scale fisheries in national and regional food and nutrition security strategies, dialogues, and policy. This evidence can be leveraged to implement successful coping mechanisms and interventions to improve food and nutrition security.

5.3 Materials and methods

5.3.1 Study sites

Household surveys were conducted between 14th December 2022 and 3rd March 2023 in three purposively selected coastal villages in Kenya (Fig. 5.1). The villages differ by remoteness (urban, peri-urban, and rural) and socio-economies. The villages were selected based on their adjacency to the ocean and hence close connection to aquatic food systems, for being situated in counties with higher poverty levels (>49%) than the national average of 38% in 2021 (Kenya National Bureau of Statistics, 2023) and with a known prevalence of nutritional vulnerabilities that need to be solved (Kamau-Mbuthia *et al.*, 2023). Watamu village (Fig. 5.1a) represents an urban site and is one of the villages within the Watamu sublocation that has a population density of 4023 people per square kilometer based on the Kenya Population and Housing Census Survey of 2019. Mkwiro village (Fig. 5.1b) was the most remote, located on Wasini Island and accessible using boats from the coastal mainland fishing village of Shimoni. The village has 327 households and a population density of 474 people per square kilometer. Vanga (Fig. 5.1c) represents the peri-urban village, characterized by 1193 households and with a population density of 1073 people per square kilometer. It is located further south, next to the border of Kenya and Tanzania.

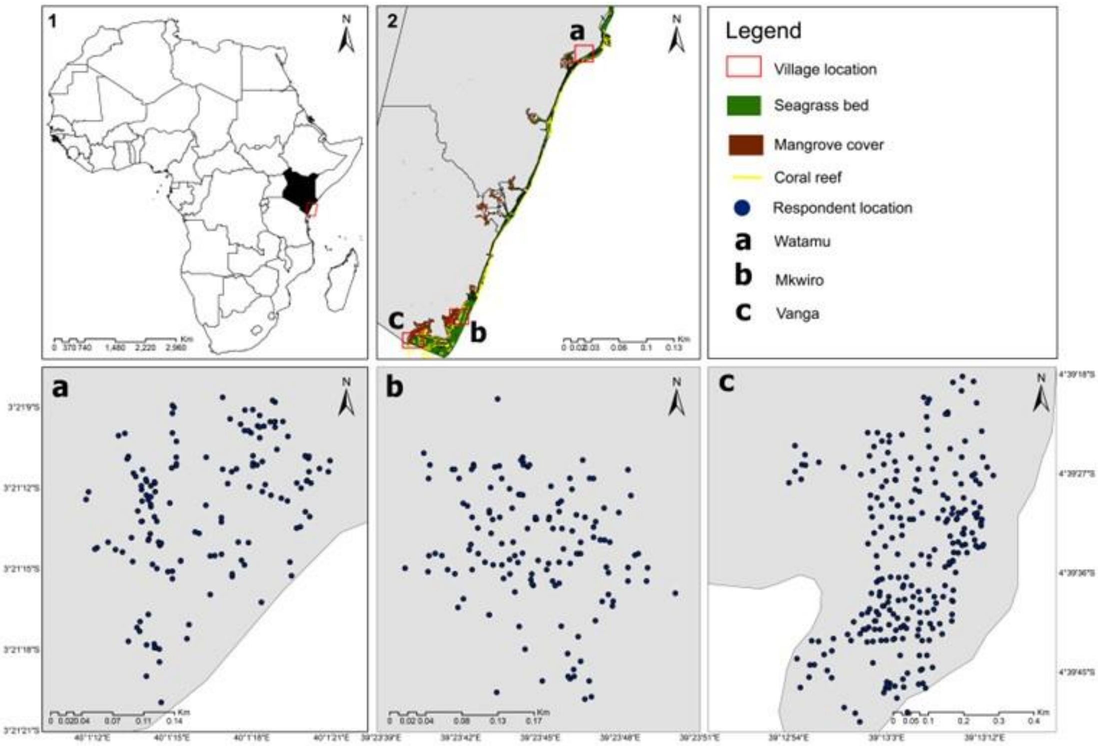


Figure 5.1 Map of Africa showing the location of Kenya (shaded) – 1, and the expanded coastal Kenya showing the 3 study villages – 2 a, b, c. Dark dots on maps a, b, and c highlight the respondent/household locations where interviews were held in Watamu, Mkwiro, and Vanga villages respectively

5.3.2 Household selection and data collection

With the help of one research assistant, I conducted household surveys targeting the person who prepared meals the previous day by using a tablet-based structured and pretested questionnaire implemented in Qualtrics software (Qualtrics, Provo, UT). Information on respondent and household socio-demographics, household dietary diversity, household fish consumption, household food insecurity experience, sanitation (types of toilet facilities), and sources of drinking water were collected. The households were surveyed following a systematic sampling design where every i^{th} household (i.e., 2^{nd} household for Watamu and Mkwiro and 4^{th} household for Vanga) was selected based on an initial sample size estimation, with i increasing with village size, to attain margin of error not exceeding 8% (https://www.zoho.com/survey/margin-of-error.html, 2023). Sample sizes depended on time, resources, study design, and selected village demographics (Table 5.1). The sample sizes fell within the acceptable margin of error between 4% and 8% at the 95% confidence level (https://www.zoho.com/survey/margin-of-error.html, 2023). A household was defined as a group of people who were living together and ate the same meals. The interviews were administered in the national Kiswahili language. The research team and village guides informed the households about the date and time of the interview 1 - 3 days in advance. Initial verbal consent to do the interviews was obtained from household heads while consent to participate in the survey was sought from the respondents.

Table 5.1 Selected sampling information and village demographics

Village	Estimated number of households	Number of households sampled	Households sampled, %	Confidence level, %	Error margin	No of people km^{-2}
Watamu	350	152	43	95	5.99	4023
Mkwiro	327	143	44	95	6.16	474
Vanga	1,193	252	21	95	5.48	1073

5.3.2.1 Respondent and household socio-demographics

The respondent sociodemographic data obtained included age, main occupation, highest education level attained, and home of origin. Household characteristics included the number of people who normally lived in the household, means of obtaining fish for consumption, type of sanitation facilities, sources of drinking water, and status of water availability in the past one month.

5.3.2.2 Household fish consumption

Respondents were asked about the frequency of fish consumption during the past week, the age at which children were first introduced to consuming fish, how diversified household fish consumption was per month by number of species or known fish taxa, estimate of how much fish the household consumed per meal and whether the household preferred fish over other animal-sourced meats. The estimate of the quantity of fish consumed per meal by the family was used to calculate the quantity of fish consumed per person per meal by dividing the reported quantity of fish consumed per meal by the number of people who ate the meal within the household. Two-way analysis of variance (ANOVA) was used to examine the statistical difference in the quantity of fish consumed per meal across the three villages (since the data met the assumption of normality of residuals and homogeneity of variance), followed by Tukey's Honestly Significant Difference test to determine where the difference occurred. The Likelihood-Ratio test using a generalized linear model based on the Poisson distribution was used to examine the differences in the number of people per household and frequency of fish consumption per week across the three villages (since these data were count data and did not follow the normal distribution). The statistical analyses were done in the Statistical Package for Social Science (IBM SPSS version 28).

5.3.2.3 Household dietary diversity

To determine dietary diversity, I utilized the standard 16-question (food groups) household dietary diversity questionnaire by FAO (Table 5.2 column 1) based on 24-hour recall by the person who prepared meals the previous day (Kennedy *et al.*, 2010; Savy *et al.*, 2007). Respondents were asked to state the foods (meals and snacks) that they or any member of the household ate or drank yesterday during the day and night, within the home, starting with the first food or drink of the morning. All foods and drinks mentioned were listed and the ingredients of composite dishes were also sought. When the respondent finished stating all foods, probing for other meals and snacks not mentioned by the respondent was done and noted down. When the respondent recall was completed, the enumerators scored food group consumption based on the information provided. These food groups were further aggregated into the standard 12 food groups to calculate the dietary diversity of households (Table 5.2 column 4) (Kennedy *et al.*, 2010). The 12-food group dietary diversity was preferred as it disaggregated fish and seafood as a separate group from flesh meats which aligned with the objective of this study.

Table 5.2 The 16 initial food groups (columns 1 and 2), examples of food items, and aggregated 12 food groups (columns 4 and 5) of the household dietary diversity assessment

Question number	Food groups	Examples of food items in the food group	Aggregation to 12 food groups	Aggregated food groups
1	Cereals	corn/maize, rice, wheat, sorghum, millet or any other grains or foods made from these (e.g., bread, noodles, porridge, or other grain products) including local foods e.g., ugali, pilau or biriani.	1	Cereals
2	White roots and tubers	white potatoes, white yam, white cassava, or other foods made from roots.	2	White roots and tubers
3	Vitamin A rich vegetables and tubers	pumpkin, carrot, squash, or sweet potato that are orange inside and other locally available vitamin A rich vegetables (e.g. red sweet pepper).	3	Vegetables
4	Dark green leafy vegetables	dark green leafy vegetables, including wild forms and locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach.	3	
5	Other vegetables	other vegetables (e.g., tomato, onion, eggplant) including other locally available vegetables.	3	
6	Vitamin A rich fruits	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these and other locally available vitamin A rich fruits.	4	Fruits
7	Other fruits	other fruits, including wild fruits and 100% fruit juice made from these.	4	
8	Organ meat	liver, kidney, heart or other organ meats or blood-based foods.	5	Meat

Question number	Food groups	Examples of food items in the food group	Aggregation to 12 food groups	Aggregated food groups
9	Flesh meats	beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects.	5	
10	Eggs	eggs from chicken, duck, guinea fowl or any other egg.	6	Eggs
11	Fish and seafood	fresh or dried fish or shellfish.	7	Fish and other seafood
12	Legumes, nuts, and seeds (pulses)	dried beans, dried peas, lentils, nuts, seeds or foods made from these (e.g., hummus, peanut butter).	8	Legumes, nuts, and seeds (pulses)
13	Milk and milk products	milk, cheese, yogurt, or other milk products.	9	Milk and milk products
14	Oils and fats	oil, fats, or butter added to food or used for cooking.	10	Oils and fats
15	Sweets	sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies, and cakes.	11	Sweets
16	Spices, condiments, beverages	spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages.	12	Spices, condiments, beverages

5.3.2.4 Household food insecurity experience

Household food insecurity experience was determined using the food insecurity experience scale (FIES) eight-item questionnaire (FAO, 2016; Cafiero *et al.*, 2018). FIES is an internationally comparable and validated indicator useful to measure each household's experience of food insecurity during the reference period of study (in this case the past 12 months preceding the household surveys). The use of a reference period of one year is consistent for purposes of annual SDG monitoring (FAO, IFAD, UNICEF, WFP and WHO, 2022). Food insecurity measurement by this indicator involved asking for a yes or no answer to whether due to limited access to food, lack of money or other resources, the household were: 1. worried about not having enough food to eat, 2. unable to eat healthy and nutritious food, 3. ate only a few kinds of food, 4. skipped a meal, 5. ate less than they thought they should, 6. ran out of food, 7. were hungry but did not eat, and 8. went without eating for a whole day (Cafiero *et al.*, 2018; Sheikomar *et al.*, 2021). The responses to these questions were aggregated to give a raw score ranging from 0 to 8, which classifies households according to the intensity of food insecurity based on the FIES that has met the assumptions of the Rasch model (i.e., acceptable infit statistic of 0.7-1.3, outfit statistic of less than 2, and Rasch reliability statistic above 0.6).

5.3.3 Data analysis

5.3.3.1 Descriptive statistics

Descriptive statistics (distribution frequencies, median and means (±standard deviation) were computed for the data on respondent and household socio-demographics, fish consumption, sanitation, and drinking water sources across the three study villages and overall.

5.3.3.2 Dietary diversity scores and dietary patterns

Dietary diversity scores were determined by summing the number of food groups consumed by households (ranging from 1 - 12). Households were also classified into 3 food frequency intake categories: 1- 4 (low dietary diversity); 5-8 (moderate diversity); and 9-12 (high dietary diversity) using the tertile partitioning method (Kennedy *et al.*, 2010; Harper *et al.*, 2022).

Dietary patterns are derivatives of the food groups in the dietary diversity and can be defined as the combination of different food groups based on the frequency with which they are consumed (Ćatović *et al.*, 2022). Using the dietary data, an extraction of the dietary patterns of the surveyed households was done using an a-posteriori approach (or data-driven method) whereby the collected dietary data was analyzed statistically to generate the combinations of foods (dietary patterns) that people consumed (Ćatović *et al.*, 2022; Zhao *et al.*, 2021). To achieve this, I conducted principal components analysis (PCA) with varimax rotation by entering the 12 food groups into the PCA procedure using the Statistical Package for Social Science version 28 (IBM SPSS version 28). I used PCA because the data extraction was based on the 24-hour recall data, the interest was to examine the overall quality of diet at the household level and that dietary patterns derived by this method show some reproducibility in different populations (Murakami *et al.*, 2019; Castelló *et al.*, 2016). However, I note that the extracted dietary patterns only explain part of the total variance of the food groups, thereby representing the optimal model related to explainable variance because the PCA method has subjectivity in selecting food groups, determining the number of principal components, selecting which foods have large factor loadings, and the patterns' nomenclature (Zhao *et al.*, 2021). Considering that a PCA output can produce as many factor solutions as the number of food groups entered, I set a criteria for retaining significant factors at an eigenvalue greater than 1.0 (Conway *et al.*, 2018; Ali *et al.*, 2020) together with an examination of the resultant scree plot break off point (Conway *et al.*, 2018; Thorpe *et al.*, 2016) and interpretability of the factors (Ebrahimi *et al.*, 2023). I used varimax rotation to attain a simple factor structure and therefore ease the interpretation of the dietary patterns (Newby *et al.*, 2004). I then used the PCA-derived dietary patterns factor loadings as continuous outcome variables to examine how they were associated with socio-demographics and fish consumption. Food groups that achieved absolute factor loadings equal to or greater than 0.30 were considered to be significantly contributing to the derived dietary pattern (Conway *et al.*, 2018). The same criteria were used for the derived household factor loadings to determine the number and percentage of households associated with each dietary pattern where households with absolute factor loadings equals to or greater than 0.30 were considered significantly associated with the dietary pattern.

5.3.3.3 Statistical validation of the Food insecurity experience scale (FIES)

The food insecurity experience scale (FIES) data was statistically validated using Item Response Theory (Rasch model) to confirm that they provided a reliable raw score measure of food insecurity that can be used as outcome variable in further analyses (Cafiero *et al.*, 2018; FAO, 2016). This was achieved using the online FIES data analysis application (https://fies.shinyapps.io/ExtendedApp/, 2023) from which the item fit statistics (acceptable infit statistic of 0.7-1.3, outfit statistic of less than 2, and Rasch reliability statistic above 0.6) were generated and interpreted (Table 5.3). This model also provided two FIES-based indicators useful for national and global food insecurity monitoring purposes:

1. $FI_{mod+sev}$ - The proportion of the population experiencing moderate to severe food insecurity
2. FI_{sev} - The proportion of the population experiencing severe food insecurity

I used these two indicators to assess the present food insecurity situation of the coastal villages relative to the national situation during 2014-2016 and 2020-2022 (FAO, IFAD, UNICEF, WFP and WHO, 2023). The 3 villages were pooled to represent coastal food insecurity, while Watamu and Vanga were retained for village-specific comparison. Mkwiro was however dropped from the village-level comparison due to the high sampling variance observed after examining the differential item functioning (DIF) plots of the Rasch model, meaning that the FIES scale could not be comparable across all 3 villages (Cafiero *et al.*, 2018; Wambogo *et al.*, 2018).

Table 5.3 Item parameters and fit statistics from the Rasch model (statistical validation model for data reliability and consistency that informed the use of FIES as a reliable dependent variable in this study). Residual correlation of <0.4 was achieved for all item pairs except 1 and Rasch reliability of >0.7 (Rasch reliability = 0.84)

Item	Severity	S.E.	Infit (0.7-1.3)	S.E.Infit	Outfit (<2.0)	N_Yes_Compl	N_if_any_valid
Worried	-1.4	0.3	1.2	0.2	0.3	337	0
Healthy	-3.0	0.5	0.8	0.3	0.1	349	0
Fewfood	-3.4	0.5	0.7	0.3	0.0	351	0
Skipped	-1.4	0.3	1.1	0.2	0.7	337	0
AteLess	-2.1	0.4	0.9	0.3	1.0	343	0
RunOut	3.7	0.2	0.8	0.2	1.2	165	0
Hungry	0.9	0.3	0.9	0.2	1.5	296	0
WholeDay	6.8	0.4	1.0	0.3	2.0	8	0

5.3.3.4 Associations between fish consumption, socio-demographics and diets and food insecurity

To assess the influence of fish consumption and sociodemographic factors on proxy measures of human health (i.e., dietary diversity, dietary diversity patterns, and food insecurity), I used generalized linear models (GLMs). A detailed description of the model input parameters is shown in Table 5.4. For dietary diversity, GLM with Poisson probability distribution and log link function was fitted, for the dietary patterns GLM with normal probability distribution and identity link function was fitted, and for the FIES raw score, GLM with multinomial probability distribution and cumulative logit link function was used (McCullagh, 2019). The GLMs were used for the analysis of the influence of the different predictor variables while accounting for confounding variables by including them in the model. Considering that the predictor and confounder variables were mixed categorical and continuous, and that the outcome variables food insecurity experience scale was ordinal while dietary diversity score was count data, generalized linear models were considered suitable (McCullagh, 2019). GLMs are similar to traditional linear models except that the error term, in general, is not assumed to be normally distributed but follows other distributions or shapes (McCullagh, 2019). The technique uses some transformation, such as a log to convert the initial set of predicted outcomes to a final set of predicted outcomes and various iterative procedures are applied to estimate the B (or slope) coefficients (McCullagh, 2019). Assessment of the strength and significance of these associations was done using odds ratios i.e., exponential of the slope B (and their 95% confidence intervals) as the measures of effect size. The GLMs were implemented using the Statistical Package for Social Science version 28 (IBM SPSS version 28).

Table 5.4 Description of the outcome and predictor variables used in investigating the influence of household fish consumption and socio-demographics on health outcomes in three coastal villages of Kenya

No	Variables and their assigned categories	Type of variable measurement scale	Indicator dimension	Variable description
	Outcome variables			
1	Dietary diversity scores	Ratio (count)	Food access and utilization	Diets composed of diverse food groups have been associated with several improved health outcomes in areas such as birth weight, child anthropometric status, and improved hemoglobin concentrations (Arimond and Ruel, 2004; Gassara and Chen, 2021). Higher dietary diversity signifies improved health outcomes (Qu *et al.*, 2022).
2	Dietary diversity patterns	Ratio (continuous)	Food access and utilization	Principal Component Analysis (PCA) derived dietary patterns reflecting what people consumed the past 24 hours in the visited households. Examining the dietary patterns reveal whether people are eating healthy foods or not hence influence on health outcomes (Cena and Calder, 2020).
3	Food insecurity experience scale (FIES) raw score	Ordinal (scale)	Food access and utilization	A globally used metric of the severity of food insecurity and indicator 2.1.2 of the SDG Goal 2.1 - Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale. Higher scores associated with food insecurity and poor health outcomes (Wambogo *et al.*, 2018).
	Predictor variables			
1	Village of residence	Nominal	Random factor/ Access	Refers to the study village where the respondent's household was located (Watamu, Mkwiro or Vanga) which are in proximity to aquatic resources and representative of urban-rural axis (remoteness/urbanicity).
2	Level of education of the respondent	Nominal	Agency/ Access	Respondents' level of education categorized into 4 tiers (none, primary, secondary, and post-secondary). Education level may shape decision-making and occupation status as well as food preparation and consumption practices.

No	Variables and their assigned categories	Type of variable measurement scale	Indicator dimension	Variable description
3	Main household economic activity	Nominal	Access/Agency	Respondents' economic activities that were categorized into 7 types (agricultural production, casual employment, fisheries production food-related business, formal employment, other business, and unemployed) as proxies of financial access that is likely to drive decision-making on obtaining fish and food.
4	Age of household respondent	Nominal	Agency	The age bracket to which the respondents fell among the 8 age groups (under 18, 18 - 24, 25 - 34, 35 - 44, 45 - 54, 55 - 64, 65 - 74, and 75 or older) with increasing age assumed to be associated with high decision-making (agency).
5	Marital status	Nominal	Agency pillar	Whether the respondent was married, divorced, never married, separated, or widowed.
6	Place of origin	Nominal	Agency pillar	The original place of birth the respondent came from (whether this community, coastal region, this country, or another country).
7	How the Household obtained the fish consumed	Nominal	Availability and Access pillar	An indication of whether the household obtained fish by purchasing from a local fisher, receiving from a fishing relative, buying from women small-scale traders, fish shop/dealer or by own fishing.
8	Number of fish species consumed per month	Nominal	Availability and Access pillar	Estimated number of fish species that the household consumed the past one month.
9	Type of household sanitation facilities	Nominal	Sanitation/Utilization/Proxy for wealth status	Access to improved sanitation facilities has been used as an indicator of utilization (WHO/UNICEF 1990-2012). It was assessed using 3 main categories (modern flushable toilets, Pit latrines, and poor facility or none).
10	Sources of household drinking water	Nominal	Water availability/Utilization/ Proxy for wealth status	Access to improved water sources has been used as an indicator of utilization (WHO/UNICEF 1990-2012). It was assessed using 6 main categories (piped water in dwelling or neighbors', protected well, public taps, rainwater, tankers by trucks or carts, and unprotected well).

No	Variables and their assigned categories	Type of variable measurement scale	Indicator dimension	Variable description
11	Monthly incidences of water scarcity	Binary	Water availability/Utilization	Assessment of whether the household had experienced water shortage in the past month. Water shortages could be attributed to hamper utilization dimension of food security.
12	Preference of fish over other meats	Nominal	Agency pillar	Whether or not the household consumed fish more than other meats categorized into 3 levels (eats more fish than meat/chicken, eats equally meat/chicken and fish, eats meat/chicken than fish).
	Predictor (covariates)			
1	Household size	Ratio (count)	Access	Household population measure of the number of people who normally resided in the household.
2	Weekly fish consumption frequency	Ratio (count)	Availability and Access	How many days during the past week the household members consumed fish.
3	Age at which children are introduced to fish	Ratio	Agency pillar	The age at which the household respondent indicated to have started introducing fish to children in that family.
4	Estimated fish consumption per person per meal	Ratio	Availability and access	An estimate of how much each person consumed per meal based on respondent's recall of the quantity of fish consumed the previous week within the household and number of people who shared the meals.

5.3.3.5 Association between dietary diversity, dietary patterns, and food insecurity

The relationship between dietary diversity, dietary patterns, and food insecurity experience was examined using multinomial logistic regression with food insecurity raw score as the dependent ordinal variable and diet parameters (diversity and patterns) as the independent variables.

5.4 Results

5.4.1 Respondents' sociodemographic factors

There were varied respondent characteristics overall and across the three villages (Table 5.5). All respondents were women with the majority aged between 25-44 years (56%). Up to 69% of the respondents were married; 71% had highest education attained as primary school (an average education equivalent to eight years) and most (38%) were unemployed while the rest were predominantly dealing in small-scale food-related businesses (25%), except Mkwiro where most (35%) were engaged in fisheries production activities. 64% of the respondents were original residents of the three villages while the rest were from other parts of the coastal region (27%), another country (7%), and the rest of Kenya (2%).

Table 5.5 Selected household survey respondents' socio-demographics overall and across the three villages (n = number of respondents, % = percent of respondents)

Sociodemographic variables	Overall		Watamu		Vanga		Mkwiro	
1. Age brackets	n	%	n	%	n	%	n	%
under 18	3	0.5	1	1	1	0.4	1	0.7
18 - 24	63	11.5	18	12	26	10.3	19	13.3
25 - 34	156	28.5	45	30	81	32.1	30	21.0
35 - 44	149	27.2	45	30	68	27.0	36	25.2
45 - 54	104	19.0	24	16	43	17.1	37	25.9
55 - 64	40	7.3	8	5	20	7.9	12	8.4
65 - 74	26	4.8	9	6	10	4.0	7	4.9
75 or older	6	1.1	2	1	3	1.2	1	0.7
2. Marital status								
Never married	44	8.0	10	7	16	6.3	18	12.6

Sociodemographic variables	Overall		Watamu		Vanga		Mkwiro	
Married	377	68.9	91	60	193	76.6	93	65.0
Separated	6	1.1	3	2	2	0.8	1	0.7
Divorced	63	11.5	29	19	18	7.1	16	11.2
Widowed	57	10.4	19	13	23	9.1	15	10.5
3. Education level								
None	90	16.5	23	15.1	51	20.2	16	11.2
Primary	388	70.9	112	73.7	168	66.7	108	75.5
Secondary	53	9.7	15	9.9	25	9.9	13	9.1
Post-Secondary	16	2.9	2	1.3	8	3.2	6	4.2
4. Occupations								
Agricultural production	11	2.0	-	-	11	4.4	-	-
Casual employment	10	1.8	6	3.9	3	1.2	1	0.7
Fisheries production	76	13.9	2	1.3	24	9.5	50	35.0
Food-related business	134	24.5	45	29.6	61	24.2	28	19.6
Formal employment	17	3.1	1	0.7	7	2.8	9	6.3
Other business	90	16.5	27	17.8	48	19.0	15	10.5
Unemployed	209	38.2	71	46.7	98	38.9	40	28.0
5. Place of origin								
Another country	41	7.5	-	-	39	15.5	2.0	1.4
Coastal region	150	27.4	57	37.5	72	28.6	21.0	14.7
This community	348	63.6	90	59.2	138	54.8	120.0	83.9
This country	8	1.5	5	3.3	3	1.2	-	-

5.4.2 Household sociodemographic factors and fish consumption

The average household size was 6.2±2.7 people with rural Mkwiro having the highest average household size of 7 people compared to Vanga and Watamu (Likelihood ratio Chi-square = 11.894, p=0.004) (Table 5.6). The average household fish consumption per person per meal the previous week was found to be 178.7±131.9 g, whereby the urban village of Watamu had the highest of 206.0±137.4 g/person/meal compared to Vanga and Mkwiro (ANOVA F = 5.869, p= 0.003). The overall mean frequency of fish consumption per week was 4.5±2.1 days with rural Mkwiro having higher mean fish consumption frequency per week of 5.5±1.7 days compared to Vanga and Watamu (Likelihood ratio Chi-square = 85.821, p=0.001). Overall, most of the households (32%) obtained fish through receiving from fishing relatives and buying from local fishers (23%) but these dynamics varied with village as was found in Mkwiro village where majority (37%) bought fish from women small-scale traders. Overall, 45% of the households had pit latrines, 31% had modern flushable toilets while 24% had poor sanitation facilities or none. There were variations in sources of drinking water with the urban village of Watamu relying on piped water within the household or at the neighbors' (99%), peri-urban Vanga depending on water pumped to a public tap (43%) and rural Mkwiro dependent upon harvested rainwater (99%). During the past month prior to the survey, 60% of the households had not experienced water shortages but many Watamu households reported having experienced some water shortage during the past month (94%).

Table 5.6 Selected household socio-demographics and fish consumption status overall and across the 3 villages (SD = standard deviation of the mean, n = number of households, % = percent of households)

Sociodemographic and fish consumption variables	Overall		Watamu		Vanga		Mkwiro	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1. Household size (number)	6.2	2.7	5.7	2.5	6.3	3.0	6.6	2.5
2. Per capita fish consumption per meal containing fish (grams)	179	131.9	206	137.4	177	129.4	154	125.7
3. Frequency of fish consumption by the family per week	4.5	2.1	3.3	2.0	4.7	1.9	5.5	1.7
4. How the household obtains fish	n	%	n	%	n	%	n	%
Buying from local fisher	123	22.5	51	33.6	44	17.5	28	19.6
Receiving from a relative's fishing	174	31.8	66	43.4	77	30.6	31	21.7
Buying from women small-scale traders	80	14.6	8	5.3	19	7.5	53	37.1
Buying from the fish shop/supermarket/dealer	90	16.5	26	17.1	51	20.2	13	9.1
From own fishing	80	14.6	1	0.7	61	24.2	18	12.6
5. Type of sanitation facilities								
Modern flushable toilets	170	31.1	56	36.8	95	37.7	19	13.3
Pit latrines	246	45.0	96	63.2	105	41.7	45	31.5
Poor facility or none	131	23.9	-	-	52	20.6	79	55.2
6. Sources of drinking water								
Piped water in dwelling or neighbours	170	31.1	151	99.3	19	7.5	-	-
Protected well	47	8.6	1	0.7	45	17.9	1	0.7
Public taps	107	19.6	-	-	107	42.5	-	-
Rainwater	157	28.7	-	-	15	6.0	142	99.3
Tankers by trucks or carts	27	4.9	-	-	27	10.7	-	-
Unprotected well	39	7.1	-	-	39	15.5	-	-
7. Monthly status of water availability								
Not experienced shortages	330	60.3	9	5.9	194	77.0	127	88.8
Experienced water shortages	217	39.7	143	94.1	58	23.0	16	11.2

5.4.3 Dietary diversity and dietary patterns

5.4.3.1 Description of the dietary diversity and dietary patterns

Based on the overall and village-specific dietary diversity scores derived from the household level 24-h recalls by the person who prepared meals the previous day, I found that cereals were the most frequently consumed food group and eggs and meat were the least frequently consumed food groups while the mean number of food groups consumed was 6.1±1.8 (Median = 6) and reported in over 50% of the households (Fig. 5.2). I established that consuming the median 6 out of the 12 food groups highlighted fish and seafood as the main animal-sourced protein in the coastal village diets irrespective of urbanicity but there was an indication that substitution with plant protein (legumes, nuts, and seeds) was more likely in Watamu than in Vanga and Mkwiro.

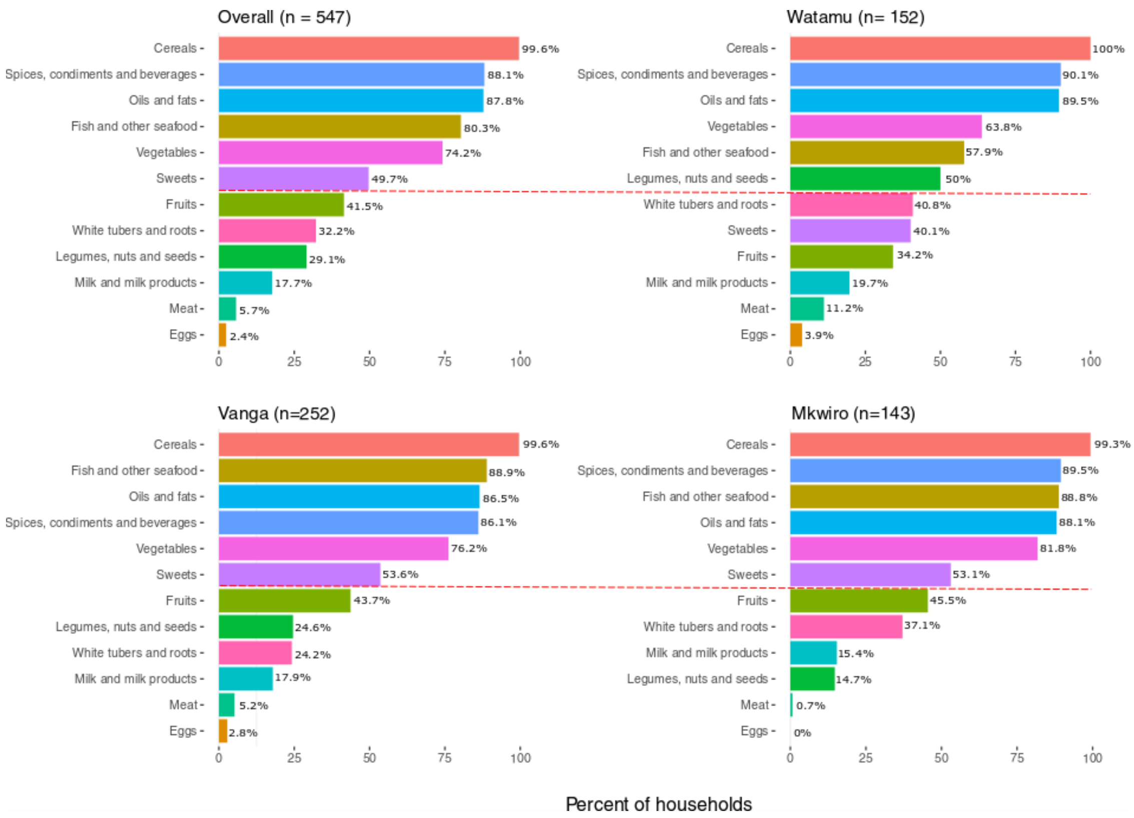


Figure 5.2 The overall and village-level percentage of household food consumption of the 12 food groups consumed in the past 24 hours. The red dotted line represents the median number of food groups (median = 6)

Based on the three food frequency intake categories, I found that 9% of the households had an adequate (high) dietary diversity (a score of 9–12), 75% had a medium dietary diversity (a score of 5-8), and 17% had a low dietary diversity (a score of 1–4) with a similar pattern revealed across the three villages (Fig. 5.3).

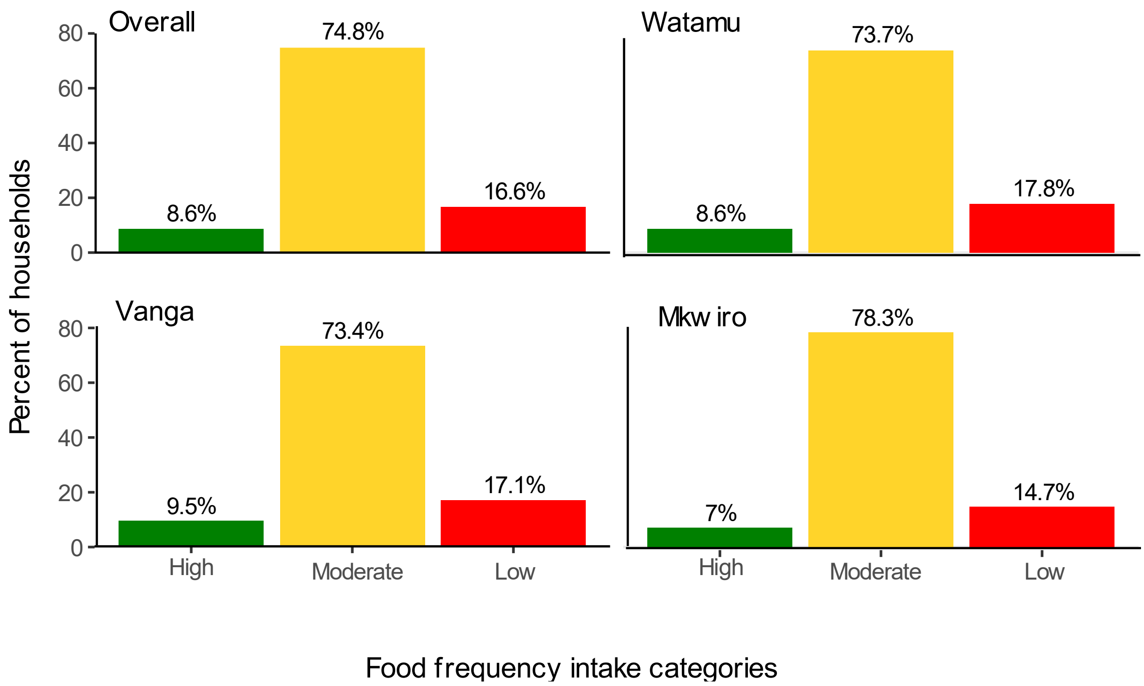


Figure 5.3 The three food frequency intake categories derived from the 12 food groups based on 24-hr recall of household food consumption (High = 9-12, Moderate = 5-8 and Low = 1-4 food groups)

Four interpretable food group dietary patterns that explained up to 46.3% of the observed dietary variations in the consumption of the 12 food groups were identified (Fig. 5.4a-d). The first dietary pattern was labelled westernized diet, which explained 14.5% of the variation and comprised of either white tubers and roots, sweets, fruits and milk and milk products (on the positive axis), or cereals (on the negative axis) (Fig. 5.4a). The majority (84%; 458 households) of households were associated with this dietary pattern. Out of these, 46% of households had consumed mainly cereals (reflected by the negative axis) and 38% consumed white tubers and roots, sweets, fruits, and milk (reflected by the positive axis) during the past 24 hours recall. The second dietary pattern was labelled seafood dominant diet, which explained 11.5% of the variation, and was characterized by either fish and seafood (on the positive axis) or meats and legumes, nuts, and seeds (on the negative axis) (Fig 5.4b). The majority (86%; 472 households) fell into the seafood dominant dietary pattern, whereby 59% of these had consumed fish and seafood while 28% had consumed either meat or legumes, nuts, and seeds during the recall period. The third dietary pattern (explaining 10.6% of the variation) was labelled cereal-rich diet and consisted of spices and beverages, oils and fats and cereals (Fig. 5.4c). Up to 82% (451 households) adhered to the cereal-rich dietary pattern, of which 60% were characterized by a high consumption of spices and beverages, oils and fats and cereals. The fourth dietary pattern, labelled lacto-ovo-vegetarian diet explained 9.7% of the variations and was mainly composed of eggs, vegetables, milk and milk products on the positive axis and fruits on the negative axis (Fig. 5.4d). About 71% (386 households) were associated with the lacto-ovo-vegetarian dietary pattern, out of which 39% had consumed fruits and 32% had consumed eggs, vegetables, milk, and milk products in the past 24 hours recall period.

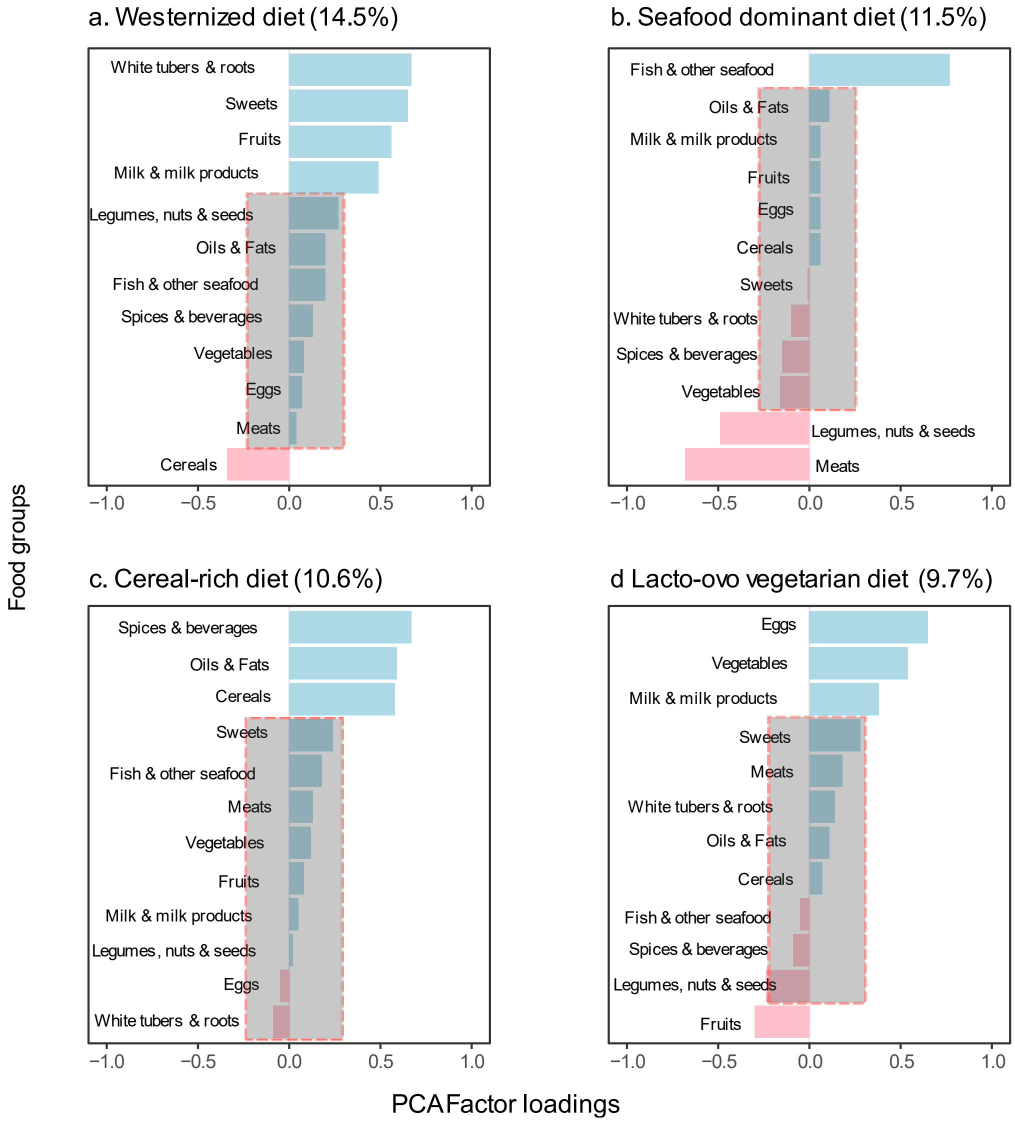


Figure 5.4 The four dietary patterns that were derived using PCA (explained 46.3% of the observed variations in consumption of the 12 food groups) and the factor loadings of the 12 food groups (the food groups enclosed in red-dotted partially opaque rectangles did not meet the set threshold absolute value of 0.3 and were considered low (n= 547)

5.4.3.2 Predictors of the dietary diversity and dietary patterns

Households that reported higher weekly fish consumption frequency were found to likely have higher dietary diversity (Fig. 5.5a). Households that were characterized by modern flushable toilets were likely to have higher dietary diversity compared with those that had poor sanitation facilities or no toilet. There was a higher likelihood of consuming a westernized diet type for households that consumed fish more times per week, had more people, had piped water in the dwelling or neighbors', had modern flushable toilets, and whose respondent was involved in food-related business (Fig. 5.5b). On the other hand, households that obtained fish through buying from small-scale traders or being given by fishing relatives had lower odds of being associated with westernized dietary pattern (Fig. 5.5b). The seafood dominant diet was significantly positively associated with households that consumed fish more times per week and with fishing households compared to households that bought from fish shops or local fishers (Fig. 5.5c). The seafood dominant diet was less likely to be consumed by households that reported water insecurity in the past month. The lacto-ovo vegetarian diet was significantly positively associated with households that had a high number of people, modern flushable toilets and those that obtained drinking water from tankers (Fig. 5.5d). Overall, the westernized and lacto-ovo vegetarian diets appeared to be the most diverse patterns and were associated with a higher socioeconomic status, and number of people in the household while the seafood dominated dietary patterns was less diverse and associated with fish consumption frequency.

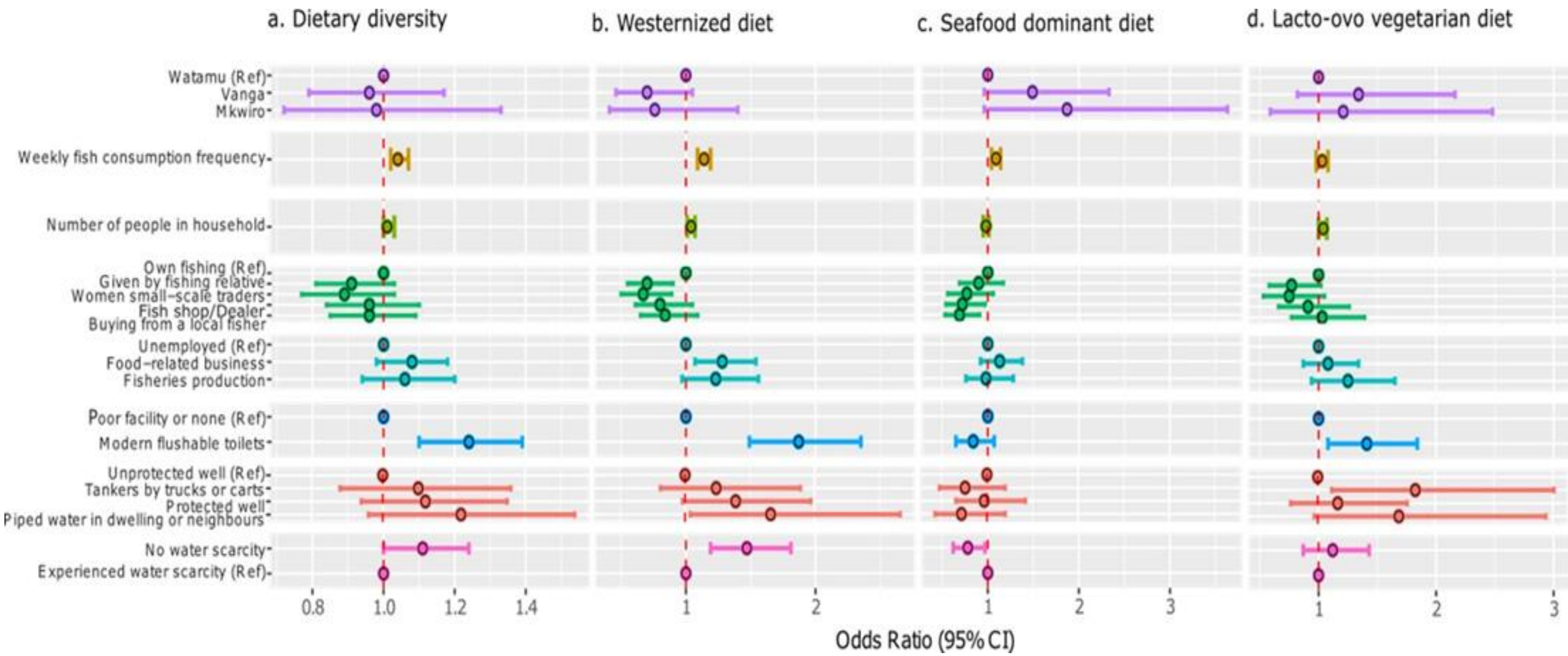


Figure 5.5 Generalized linear model results showing the significant predictors on any of the dietary diversity and dietary patterns response variables (cereal-rich dietary pattern was not significantly influenced by any of the predictors and is not shown here); red-dotted line indicates the no-effect Odds Ratio = 1 reference point with values greater than 1 showing higher odds of association and values less than 1 showing lower odds of association with dietary diversity or dietary pattern, Villages (Watamu, Vanga and Mkwiro) were included as the random factors

5.4.4 Food insecurity

5.4.4.1 Description of the food insecurity situation

The three coastal villages had a higher percentage of households experiencing both severe (33.6%) and moderate or severe (90.7%) food insecurity compared to data compiled from The State of Food Security and Nutrition in the World Report (FAO, IFAD, UNICEF, WFP and WHO, 2023) on the national averages of 15% and 28% during 2014-2016 and 2020-2022 for severe and 51% and 72% during 2014-2016 and 2020-2022 for severe and moderate or severe food insecurity respectively (Fig. 5.6). The urban village of Watamu had more households experiencing severe food insecurity and moderate or severe food insecurity than the peri-urban Vanga village. Generally, the national trend in severe food insecurity and moderate or severe food insecurity is on an upward trajectory by up to 87% and 43% respectively in 2020-2022 relative to 2014-2016.

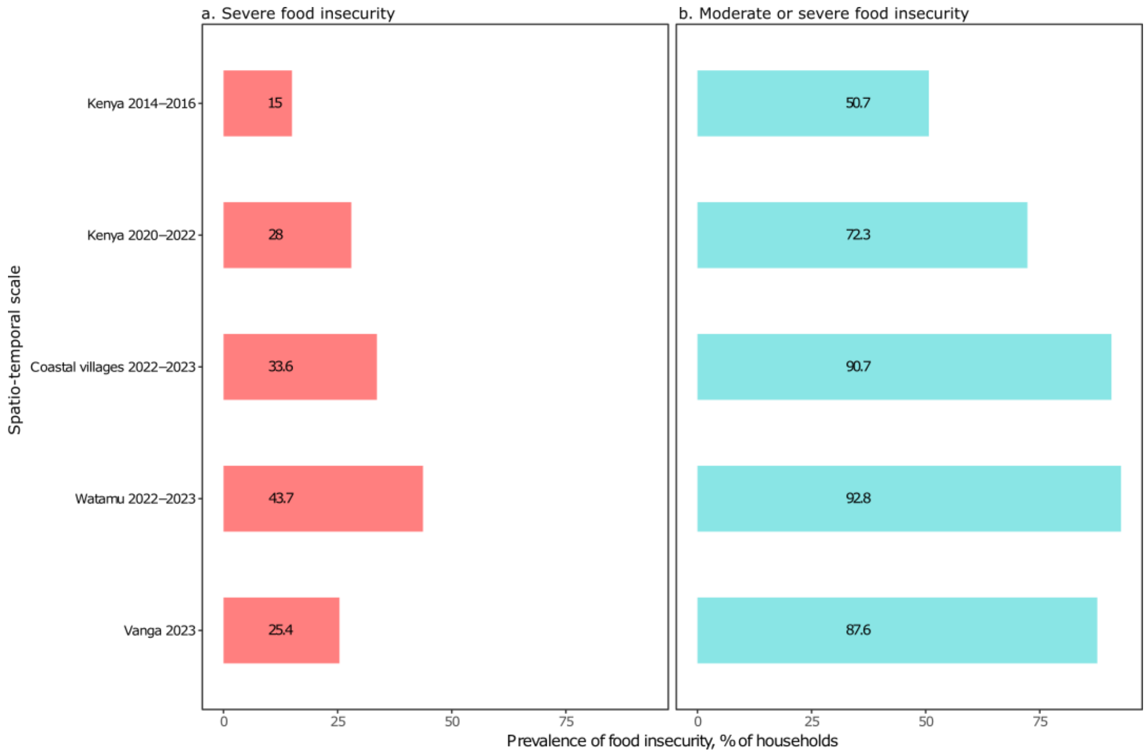


Figure 5.6 Prevalence of a. severe food insecurity (FI_{sev}) and b. moderate or severe food insecurity ($FI_{mod\text{-}sev}$) in Kenya during 2014-2016 and 2020-2022 and for the combined coastal villages during 2022-2023, Watamu 2022-2023 and Vanga-2023

5.4.4.2 Predictors of food insecurity

There were decreasing odds of being food insecure for households where the respondents' main jobs were fisheries production, food-related business, and formal employment compared to the unemployed (Fig. 5.7). Households where the respondent had no formal education and where the respondent had attained only primary level of education were more likely to be food insecure compared to those where the respondent had post-secondary level education (Fig. 5.7). The likelihood of experiencing high food insecurity increased depending on where or how the household sourced fish for home consumption, being significant for those that bought fish from women small-scale fish traders or were given by a fishing relative or bought from local fishers compared to those who did their own fishing. Households that had modern flushable toilets were more likely to be food secure compared to those that had pit latrines or poor sanitation facility/none. Households that consumed fish more times per week were less likely to experience higher food insecurity.

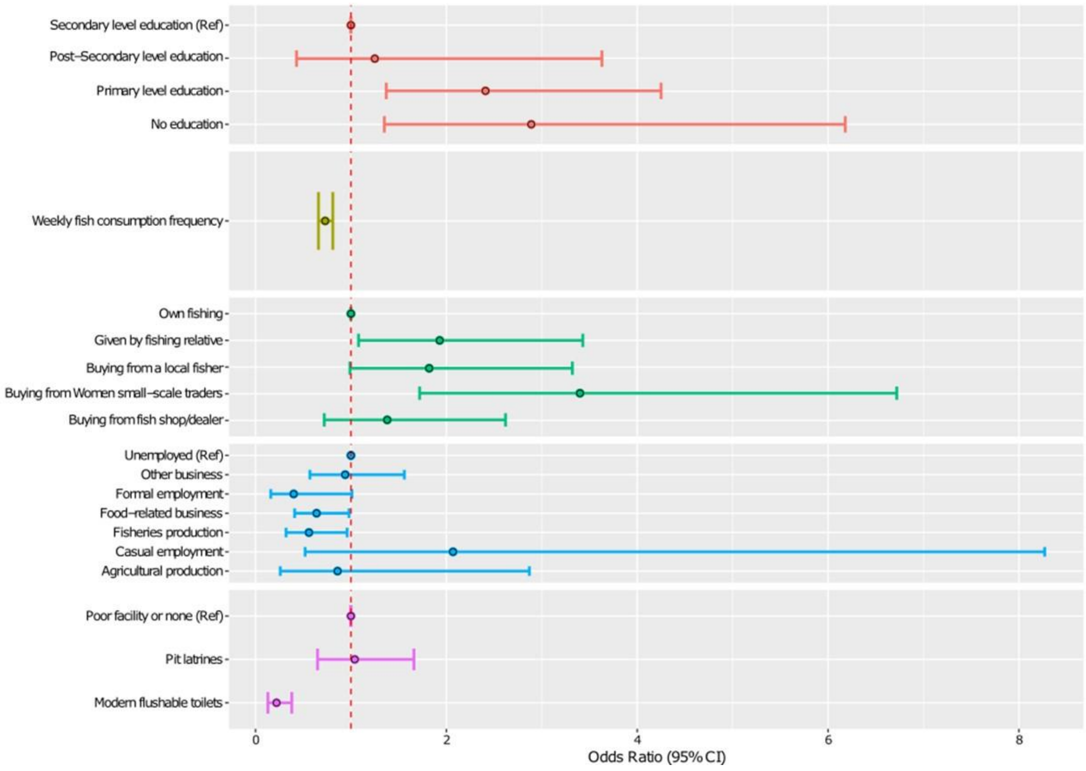


Figure 5.7 Generalized linear model results showing predictors of food insecurity; red-dotted line indicates the no-effect Odds Ratio = 1 reference point with values greater than 1 showing higher odds of food insecurity and values less than 1 showing lower odds of a household experiencing food insecurity

5.4.5 Association of dietary diversity, dietary patterns, and food insecurity

Households that were characterized by the most diverse of the four dietary patterns (westernized dietary type or lacto-ovo vegetarian diet) had lower odds of food insecurity, while there was no significant association between food insecurity and dietary diversity score, seafood rich diet and cereal-rich diet (Fig. 5.8). Therefore, there was higher likelihood of households consuming the westernized or lacto-ovo vegetarian dietary pattern being food secure than those that did not.

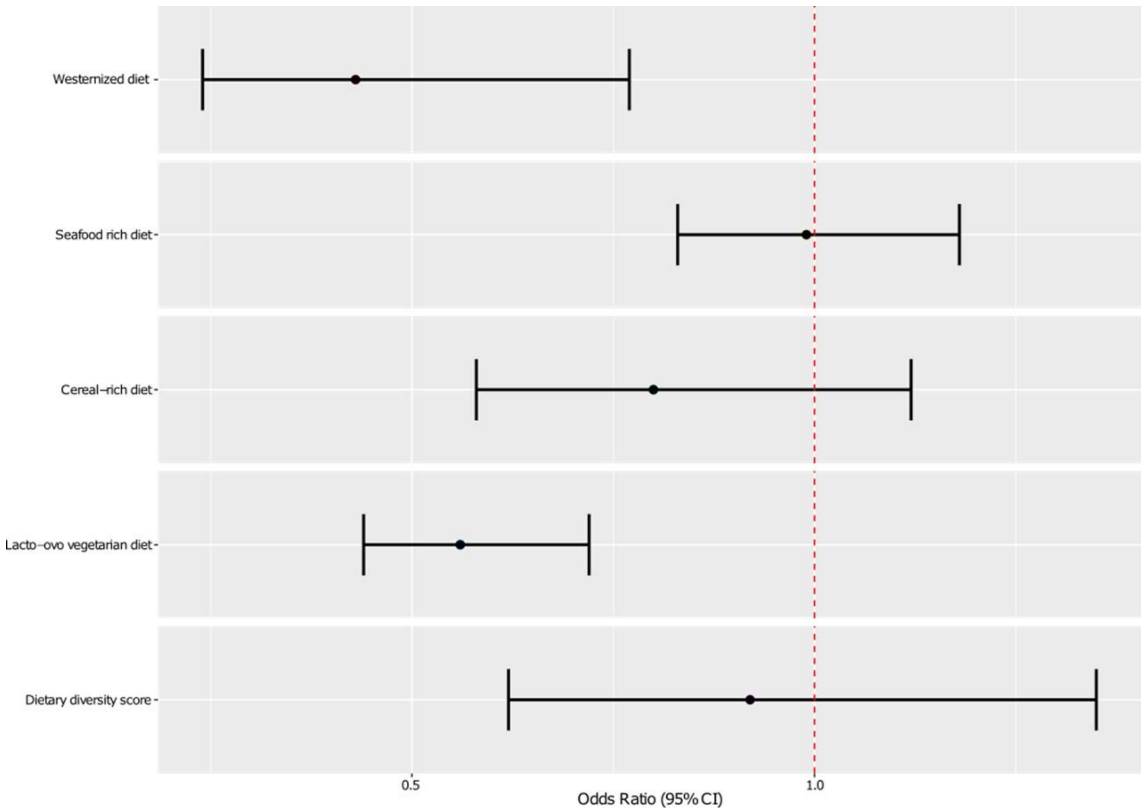


Figure 5.8 Generalized linear model results showing the association of dietary diversity and dietary patterns with food insecurity experience; red-dotted line indicates the no-effect Odds Ratio = 1 reference point with values greater than 1 showing higher odds of food insecurity and values less than 1 showing lower odds of a household experiencing food insecurity

5.5 Discussion

Through this study, it was found that households that consumed more fish per week, had access to modern sanitation facilities, and adequate supply of drinking water were more likely to report a higher dietary diversity. Households where respondents had higher levels of formal education (post-primary), were involved in fisheries production, food-related business, formal employment, consumed more fish or had access to modern sanitation facilities, were less likely to be food insecure. Three of the four dietary patterns were associated with higher rates of fish consumption but had varied associations with sociodemographic factors. Overall, the fish food system contributed directly to dietary diversity, healthier dietary patterns, and food security by providing essential food items (seafood) and indirectly to food security as a livelihood resource (employment). I discuss these findings in the context of assessing the predictors of human health outcomes that are important to establish whether Kenya is moving towards meeting the SDG 2 and national and continental food and nutrition security commitments at this local level. Furthermore, I highlight the importance of fish for food and nutrition security in coastal communities based on its role in dietary diversity, dietary diversity patterns and food insecurity experience. The sociodemographic factors that were associated with these health outcome proxies are also discussed.

5.5.1 Household dietary diversity and dietary patterns reveal gaps for nutrition improvement

The average dietary diversity score that was obtained in this study of 6 food groups approximates the national average dietary diversity score of 5.6 obtained using the Kenya national dietary quality questionnaire data collected during 2021-2022 (Global Diet Quality Project, 2023) although the latter was based on 10 food groups. These scores indicate adherence to the national dietary guidelines for healthy living recommendations of eating foods from at least 4-5 food groups in a daily eating plan (KNBS and ICF, 2023; Ministry of Health, 2017) and preliminary recommendation to have at least 4 food groups for a healthy diet (Habte and Krawinkel, 2016). This was reflected in the fact that over 70% of the coastal households consumed 5-8 food groups (moderate food intake frequency category). Despite this, dietary diversity and patterns revealed exclusion of important recommended food groups such as fruits, milk and milk products and reliance on only one animal sourced food (i.e., fish and seafood) yet it is recommended to vary choices within each food group from day-to-day, depending on what is in season, available and affordable (Ministry of Health, 2017). This indicates the high likelihood of fish and seafood being a key source of food and nutrition security in these communities. Recommendations for sustainable healthy diets suggest a balance across food groups, that include wholegrains, legumes, nuts and an abundance and variety of fruits and vegetables and moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat (FAO and WHO, 2019). Therefore, improving dietary diversity would require having more choices (expanding the agency dimension of food and nutrition security) but these are often constrained in the local situation due to various reasons (discussed below) and others not covered in this study.

Factors that were associated with higher odds of a high dietary diversity score included having modern flushable toilet facilities, reliable water availability and high frequency of fish consumption. These factors reflect measures of household wealth, with the latter indicating better fish access. Dietary diversity has been positively associated with household asset-based wealth, income and high socio-economics (Olielo, 2013; Korir *et al.*, 2023; Commission on Social Determinants of Health, 2008; Kihiu and Amuakwa-Mensah, 2021; Miller *et al.*, 2022). The predominance of fish as the main source of animal protein indicates its pivotal role in meeting the nutritional needs of the coastal people. This concurs with similar observation among communities with higher consumption of staple-based diets using fish as the main animal-based protein (Belton and Thilstead 2014).

The results found here provide for further assessment of the dietary quality of coastal communities and determination of whether they are meeting recommendations such as choosing foods from different food groups, and different foods from within each food group (Ministry of Health, 2017). Healthy diets have been found to incorporate fruits, vegetables, fish, legumes, nuts and whole grains (Cena and Calder, 2020; Fadnes *et al.*, 2022). To attain such a combination based on our results, there would be a need to draw from different combinations of the dietary patterns. The observation that majority of the households (up to 60%) were significantly associated with the cereal-rich dietary pattern indicates the fact that these households may not be accessing healthy foods and are thus undergoing a nutrition transition to nutrient-inadequate staples and sugary beverages that reflect unavailability and unaffordability of healthy foods (Korir *et al.*, 2023; FAO and WHO, 2019). Coastal diets tend to be monotonous and dominated with staples (cereals, cassava and bananas) obtained through different means (Klaver and Mwadime, 1998). Cereals and pulses (legumes, nuts and seeds) are commonly consumed within Kenya with maize dominating the food security situation in the country (Kenya National Bureau of Statistics, 2019; Ekpa *et al.*, 2019).

Fish and seafood was found to be an integral component of coastal diets, emerging as a seafood dominant dietary pattern being substituted for by legumes (beans and peas) and meats which tend to be consumed together. The co-occurrence of legumes and meat together on the seafood dominant dietary pattern concurs with a previous study establishing that the coastal zone has low consumption frequency of meats and beans, with these two being positively correlated (Klaver and Mwadime, 1998). The consumption of meat and beans could be due to possible local preference of combining meat and beans or other factors not yet explored (Klaver and Mwadime, 1998). The findings reveal that fish consumption and therefore aquatic food systems are important for human nutrition gains in the coastal communities, but an interplay of contextual sociodemographic factors is key to improving access, agency, and utilization of fish.

5.5.2 Household food insecurity hamper the achievement of nutrition outcomes for health

There was high prevalence of severe food insecurity and moderate or severe food insecurity in the coastal villages compared to the global and national average, indicating that households did not have access to adequate quantities of food in the past 12 months. The general trend of food insecurity revealed worsening food security in Kenya due to factors such as global forces driving prices up, economic slowdowns, and the consecutive years of below average rainfall bringing drought like conditions and growing inequality as is the case in the rest of Africa where moderate or severe food insecurity from 2021 to 2022 has not yet improved (FAO, IFAD, UNICEF, WFP and WHO, 2023). Similar patterns have been observed in a recent study on access to food in seven countries (Cameroon, Democratic Republic of the Congo, Guinea-Bissau, Haiti, Liberia, Rwanda, and Zambia) faced with food security crises (Cafiero *et al.*, 2023). There are complexities in the major drivers of food insecurity and malnutrition which often co-occur and pose challenges to interventions for achieving food and nutrition security (FAO, IFAD, UNICEF, WFP and WHO, 2023). Therefore, identifying and addressing food insecurity by leveraging on significant predictors to improve health outcomes is paramount when formulating policies to meet set targets at global, regional, national, and subnational levels.

Food insecurity was positively associated with households whose respondents had no education or low levels of education, dependence on alternatively cheaper sources of fish (being given by a fishing relative, buying from local fishers and women small-scale traders) and type of employment. Severe food insecurity has been found to be prevalent among individuals who were based in rural areas, less educated, unemployed and with lower incomes similar to findings from other selected Sub-Saharan African countries (Wambogo *et al.*, 2018). Higher socio-economic status, better education, and higher asset-based wealth has been associated with food secure households (Mahdavi-Roshan *et al.*, 2021; Bandyopadhyay *et al.*, 2021; Mohamadpour *et al.*, 2012; Kihiu and Amuakwa-Mensah, 2021) while household poverty worsens food insecurity (Food Research & Action Center, 2017; Smith *et al.*, 2000). Education influences social mobility by elevating individuals and households out of poverty (Mutisya *et al.*, 2016), leading to food security directly through enhanced income returns, improved health and better decision making (McMahon, 2009).

Other sociodemographic factors such as means of obtaining fish from women small-scale traders, local fishers or being freely given by a fishing relative may be related to the lack of money and high dependence on others. The women small-scale traders and local fishers represent a market sector that offers affordable fish to low-income households. Previous studies in coastal Kenya found that the women small-scale traders offered cheaper fish through selling affordable portions (Matsue *et al.*, 2014; McClanahan and Abunge, 2017). Results from chapter 3 (this thesis) show that small-scale women traders play an important role in making fish available in smaller portions that can be accessed by poor households. The associations of wealthier households (indicated by main job of the respondent, education levels, type of toilet facilities and sources of water for consumption) and fishing households with lower odds of food insecurity have been observed in parts of the coast (Darling, 2014). Households where respondents were in formal employment, food-related business and fisheries production activities were likely be food secure, highlighting the role of fisheries as a double-edged livelihood resource providing fish for consumption and money for purchasing other food items (Fiorella *et al.*, 2014; Roberts *et al.*, 2023).

The importance of food and nutrition security to improving people’s health outcomes cannot be understated (Beyene, 2023; Giller, 2020). Considering that most households in coastal villages were experiencing moderate to severe food insecurity, there is a need for improvements to achieve food and nutrition security.

Household members that experience moderate food insecurity have reduced the quality and/or quantity of their food and are unsure about their ability to obtain food due to lack of money or other resources. Moderate food insecurity can increase the risk of some forms of malnutrition, such as stunting in children, micronutrient deficiencies or obesity in adults (FAO, IFAD, UNICEF, WFP and WHO, 2023; Gassara and Chen, 2021). People experiencing severe food insecurity have run out of food and, to the extreme, have gone for days without eating. This group of people are those identified as the “hungry” and are prone to poor nutritional outcomes (Tiwari *et al.*, 2013; Wambogo *et al.*, 2018; Cafiero *et al.*, 2023; FAO, IFAD, UNICEF, WFP and WHO, 2023).

5.5.3 Diverse dietary patterns may help alleviate food insecurity

There were mixed associations between food insecurity and dietary diversity and patterns. Consuming the westernized and lacto-ovo vegetarian dietary patterns was found to be related to food security attainment, which could be attributed to the fact that the two dietary patterns were characterized by four food groups, indicating the likelihood of being food secure for households that consumed four or more food groups. This finding resonates with the Kenya dietary guidelines that recommend consuming at least four food groups daily per meal plan to achieve health lives (Kenya National Bureau of Statistics, 2019). The seafood dominated and cereal based dietary patterns were the predominant diets but were characteristically less diverse with only three food groups and not significantly associated with food insecurity. Similarly, there was no significant association between dietary diversity score, and food insecurity indicating that dietary diversity alone may not be an appropriate indicator of food insecurity in these coastal villages of Kenya. Although dietary diversity was found to show some promise as a measure of food security (Hoddinott and Yohannes, 2002), this study indicates some level of uncertainty. Similar findings have been observed in Karachi, Pakistan where severe food insecurity levels were inversely related to household dietary diversity (Hashmi *et al.*, 2021), and within semi-arid agro-ecological zones in Eastern Kenya where no relationship was found (Bukania *et al.*, 2014). This implies that household food insecurity may or may not co-occur alongside lower dietary diversity. Therefore using both food insecurity and dietary diversity (Gassara and Chen, 2021; Tambe *et al.*, 2023) as outcome variables for health outcomes reveals more gaps for appropriate interventions to address food and nutrition security.

5.6 Conclusions

In this chapter, I investigated the impact of fish consumption and household sociodemographic factors on dietary diversity, dietary patterns, and food insecurity in coastal households of Kenya. The findings emphasize the importance of fish as a significant source of animal-based protein for coastal village households in Kenya, complemented only by legumes and meats occasionally. Further, I reveal that local fish markets are crucial for food security, with households relying on low-cost market segments such as women small-scale traders and local fishers facing higher levels of food insecurity. Factors such as higher education levels, socio-economic status, frequency of fish consumption per week, and employment were found to be important in achieving food security. I highlight the need for strengthened nutrition-sensitive and specific activities to reduce food insecurity and promote balanced diets for human health. Overall, the fish food system contributes directly to dietary diversity, dietary patterns, and food security as essential food items and indirectly to food security through employment opportunities that generated money for purchasing other foods.

These findings have significant policy implications for interventions aiming to support fish food systems transformations to improve food security and diets for healthy populations. Suggested interventions include improving market access to fish (especially for households reliant on the risk-prone market sectors), addressing poverty, enhancing education levels, promoting healthy dietary habits, creating reliable employment opportunities, and increasing awareness of nutritionally beneficial dietary patterns. These interventions are particularly relevant for individuals and households with lower socioeconomic status and education levels, who tend to be more vulnerable.

Research gaps identified for further investigations include scaling down to intrahousehold fish and food consumption patterns to identify individual-specific health outcomes. This is because effective nutrition needs to be considered at the individual level, as it depends on every individual's age, sex, food allocation, bodily condition and other factors that were beyond the scope of the present study. Future research is proposed to refine the food insecurity experience scale as an indicator to compare results across various subregions or villages.

Chapter 6. General discussion, conclusions, and future research directions

6.1 General discussion

6.1.1 Introduction

Food and nutrition security continue to feature as a challenging pursuit for humanity (FAO, IFAD, UNICEF, WFP and WHO, 2023; HLPE, 2020; FAO, 2022b), since it impacts nutritional status and other health outcomes (Cuenca *et al.*, 2023). There have been calls to repurpose food policy support to make healthy diets more affordable, sustainable, and inclusive (FAO, IFAD, UNICEF, WFP and WHO, 2022; Fang and Gurinović, 2023; Simmance *et al.*, 2021). One sector that holds the potential to help address the health challenge of malnutrition is fisheries, yet it remains understated or overlooked in food policy (Koehn, 2019; Bennett *et al.*, 2018, 2021a; Hicks *et al.*, 2019; Stetkiewicz *et al.*, 2022; Arthur *et al.*, 2022; Rivero *et al.*, 2022). Although there has been some increased recognition of the relationship between aquatic foods and food security and nutrition in policy and practice, gaps still exist in monitoring frameworks and governance instruments to fully acknowledge or support this (Farmery *et al.*, 2021). Fisheries in general, and tropical small-scale fisheries in particular, are depended upon by many marginalized and poor rural households that have low uptake of other animal-sourced foods (FAO, IFAD, UNICEF, WFP and WHO, 2023; Jyotishi *et al.*, 2021; de Bruyn *et al.*, 2021; Thompson and Amoroso, 2014; Cisneros-Montemayor *et al.*, 2016). However, fish consumption deficits have been reported in low- and middle-income Sub-Saharan countries (Obiero *et al.*, 2019; Tran *et al.*, 2019; Muringai *et al.*, 2022; FAO, 2022b) that are known to be most vulnerable to nutritional deficiencies (Simmance *et al.*, 2021). It was based on this context, that I sought through this thesis to ask: "*What factors influence the use of fish for food and nutrition security in Kenya*?"

In this thesis, I have identified how fish could be used to support greater food and nutrition security in Kenya. I have done this by working along, from the first pillar of food and nutrition security (availability), to access, agency, utilization, to finally discussing the implications of stability and sustainability across the other four pillars. My use of an interdisciplinary approach was guided by the understanding that food systems are complex and multi-sectoral (HLPE, 2020, 2017; El Bilali *et* *al.*, 2019) while the fishery is also a complex socio-ecological system (Ostrom, 2009; McGinnis and Ostrom, 2014). Both systems call for management and governance involving many ministries and state departments responsible for different aspects peculiar to each system. For example, to address transformation of the food system in Kenya, at a minimum, ministries, and departments responsible for agriculture, livestock, fisheries, industry, transport, environment, health, nutrition, social welfare, economic planning, finance, employment, and devolved governance units should be included. This calls for a holistic and integrated approach if the fishery system is to be mainstreamed to build a sustainable food system (Kelling *et al.*, 2023) and develop an informed understanding of the needs, impacts and solutions (Farmery *et al.*, 2022). Therefore, my research findings contribute new data and evidence that can support Kenya's aspiration to anchor fish generally, and small-scale fisheries specifically, in national food and nutrition policy and strategies that ensure resource adjacent communities and the most vulnerable are not left behind.

6.1.2 Synthesis of thesis

Unpacking the various factors that either enable or constraint people's use of fish to help alleviate nutrient deficiencies while ensuring equity and sustainability is crucial to supporting a food system transformation (Simmance *et al.*, 2021). This is important, especially for communities that are highly dependent on seafood for healthy diets, food and nutrition security, and other livelihoods. This thesis provides empirical evidence of the factors identified to influence food and nutrition security that people encounter or perceive in their attempt to harness tropical aquatic food systems. The thesis addresses an important gap in the literature, policy, and practice, and helps underscore the opportunities to transform fish food systems through nutrition sensitive governance and management.

By addressing the first research question (Chapter 2), this thesis elicited a national outlook of available fish supplies and their potential to contribute to alleviating nutritional deficiencies of important nutrients such as calcium, iron, selenium, zinc, and omega-3 fatty acids. I show that amid inadequate availability, food and nutrition security could be supported by targeting the available supply of fish towards meeting the needs of the most vulnerable, for example children under five years, lactating mothers, pregnant women, or rural populace close to the fishery water bodies. Such a call for targeting is important in achieving equity and ensuring the nutritional needs of the most in need are met (Allegretti and Hicks, 2022; Byrd *et al.*, 2021a; Bonham *et al.*, 2009). Based on the temporal analysis of fish supplies, I caution that declines in available supplies from freshwater sources have led to reduced nutrient yields due to declining stocks of nutrient dense fish such as *R. argentea* (locally known as “omena” or “dagaa”). Therefore I propose the need to improve fisheries resource management to ensure that fish biodiversity is maintained to meet diverse nutrient portfolios for human health (Heilpern *et al.*, 2023).

In answering the second research question (Chapter 3), I reveal the role of fish markets in mediating the availability of and access to nutritious fish by communities at the subnational level. Here, I contribute empirical evidence on the intersection of the nutrient content of commonly traded fishes and the potential they hold to help meet fish consumption needs and reduce nutritional deficiencies in coastal Kenya. For example, I show that there are cheaper and more nutritious fish available across different traders, that can be harnessed for a healthy diet rich in calcium, iron, zinc, selenium, and omega-3 fatty acids. This evidence may be applicable in other parts of the country, and other developing countries where studies exploring the nutrient content of fish traded in local markets are needed, especially those with low per capita fish consumption and where malnutrition remains a challenge. This is critical considering that one of the metrics that needs redressing to inform policy and funding decisions around food security has been a lack of information on nutrient content of fish (Bennett *et al.*, 2021a). Consequently, this evidence forms a basis for the transformation of fish trading to being nutrition-sensitive (Bennett *et al.*, 2022; Allegretti and Hicks, 2022).

The third research question (Chapter 4) led to the identification of social processes and power dynamics that influence access and agency pillars of food and nutrition security in coastal communities through the perceptions of key informants. This was driven by the understanding that to improve fish availability through existing supplies and trade and enhancing access through trade form an important part of desired change to transform a food system but these are limited to the structural level (policies, practices and resource flows) of system change

(Kania *et al.*, 2018). Therefore, there was a need to move to considerations of relational change (relationships and connections, and power dynamics) as well as transformative change (mental models, beliefs and attitudes) (Kania *et al.*, 2018) associated with obtaining fish. Consequently, I unraveled the existent social processes and power dynamics influencing access and agency using key informants' perceptions. These included conditions for agency (environmental, social, and personal conversion factors) and mechanisms of access (structural and relational mechanisms of access and rights-based access mechanisms). An interplay of factors have been associated with access (Ribot and Peluso, 2003; Peluso and Ribot, 2020) and agency (Manlosa, 2022) about harnessing fisheries resources. Here, I established that there are complex multiple conditions of agency and mechanisms of access, but which could be leveraged in policy and practice as enablers and or constrains, depending on the contexts in the endeavor to achieve food and nutrition security through fish food systems.

The fourth research question (Chapter 5), built upon a combination of the first three research questions by seeking to examine fish consumption at the household level to identify factors that influence fish consumption and food and nutrition security. I assessed how fish consumption and socio-demographic factors influence dietary diversity, dietary patterns, and food insecurity. The latter three have been linked to health, I therefore used them as proxies of health outcomes and to capture elements of the utilization pillar of food security (Tambe *et al.*, 2023; Boateng *et al.*, 2019; Cena and Calder, 2020). Thesis findings revealed key policy implications for interventions aiming to support fish food system transformation to achieve food and nutrition security in coastal households. Findings showed high prevalence of food insecurity and moderate dietary diversity and less diverse dietary patterns, irrespective of urbanicity. Fish was found to be the main animal source food in the studied coastal households. Overall, I bring to light the understanding that the fish food system contributes directly to dietary diversity, dietary patterns, and food security by providing essential food items (seafood) and indirectly to food security as a means of livelihood (employment). Specifically, I identify interventions for improving human health outcomes including addressing poverty, enhancing education levels, promoting healthy dietary habits, creating reliable employment opportunities, and increasing awareness of nutritionally beneficial dietary patterns. These interventions are particularly relevant for individuals and households with lower socioeconomic status and education levels, who tend to be poor or marginalized, and with limited resources to afford healthy diets.

While I make various recommendations regarding the four research questions examined in this thesis (see the summary in Table 6.1), generally, I: 1. attempt to shine light on the nutritional profiles and nutrient density of the fish supplies in Kenya, 2. highlight the potential of the various fish nutrients yields to tackle nutritional deficiencies, and 3. unravel the various factors across the different pillars of food and nutrition security that need considering towards holistic attainment of a healthy people albeit with the necessary targeted interventions that would ensure proportionate universalism is attained.

Table 6.1 Summary of thesis recommendations across the six pillars of food and nutrition security that could be leveraged to transform Kenya's fish food systems

No.	Pillar of food and nutrition security	Thesis chapter(s)	Recommendations for policy interventions and improvements
1	Availability	2 & 3	Increase fish supply, through a combination of improved fisheries management, restoration of declining fish stocks, maintenance of high fish biodiversity, investment in nutrient rich aquaculture and imports to meet food and nutrition needs for all people.
			Direct available fish to target the needs of the most vulnerable/ in-need or resource-adjacent populations through cross-sectoral working together by the relevant actors (e.g. identified households or communities, fisheries scientists, public health practitioners, policy and governance agents, etc).
			Recognize that all market traders are important facilitators of fish availability by providing fish handling infrastructure support and making them aware of the unique role they are playing for nutrition security.
			Promoting nutrition-sensitive fish trade that facilitates availability of fish by providing information that highlights nutrient composition of the commonly traded fish.
2	Access	3, 4 & 5	Recognize that all market traders are important facilitators of fish access by making them aware of the unique role they are playing for nutrition security through trainings or information sharing and supporting interventions that promote fish trade, especially for the vulnerable market actors such as women small-scale fish mongers.
			Promoting nutrition-sensitive fish trade that facilitates access to fish by providing information that highlights nutrient concentration of the commonly traded fish.
			Promote the identified enabling mechanisms of access such as knowledge about fishing practices, compliance with licensing requirements, how to access financial support and markets by supporting interventions that improve their attainment.

No.	Pillar of food and nutrition security	Thesis chapter(s)	Recommendations for policy interventions and improvements
			Identify interventions to overcome the identified constraining mechanisms of access (e.g. illegal fishing, financial limitations, lack of market access, and inadequate fishing technology) to fish for nutrition security.
3	Agency	4 & 5	Promote the identified enabling conditions of agency (such as fish preparation and cooking knowledge, social relationships, consideration of fish as a healthy diet and fish availability) through interventions that help maintain them to support improved nutritional outcomes.
			Identify interventions to help overcome the identified constraining conditions of agency (e.g. unavailability of fish, climate change effects, meeting other livelihood need, constraining cultural norms) to achieve transformation of fish food system to being all-inclusive.
4	Utilization	5	Promote fish consumption of the available nutritious fish species by creating awareness to communities, especially household caregivers of the nutritional importance of fish to the diets of coastal communities.
			Sensitization on nutritional significance of available fish species for nutrition security by sharing information on nutrient concentrations of species with communities and practitioners.
			Implement interventions that promote improvements in dietary diversity, dietary patterns, and food insecurity within households that are prone to inadequacies such as those that were characterized by poor sanitation, low levels of education, poverty and unemployment.
5	Stability	All	Promote the adoption of nutrition-sensitive management and governance interventions that ensure stability across availability, access, agency, and utilization of fish for food and nutrition security by engaging with relevant multiple actors at the national, subnational, community and household level.
6	Sustainability	All	Promote the adoption of nutrition-sensitive management and governance interventions that ensure sustainability across availability, access, agency, and utilization of fish for food and nutrition security by engaging with relevant multiple actors at the national, subnational, community and household level.

The determinants revealed in this thesis formed a basis for the modification of the initial theory of change (HLPE, 2020) to make it applicable to the Kenyan context. The modified theory of change (section 6.1.3) illustrates how this thesis could contribute to supporting fish food system transformation aimed at achieving the food and nutrition security agenda. Therefore, in combination, the whole thesis untangles the factors spanning the six pillars of food security, that could be leveraged in policy and practice to achieve sustainable fish food system transformation for food and nutrition security.

6.1.3 Modified theory of change to achieving food and nutrition security in Kenya

Through this thesis, I unfold five main ways within the confines of the five critical policy elements, six pillars of food and nutrition security, and the need to attain relevant sustainable development goals (in this case SDG 2) (HLPE, 2020) as well as other food and nutrition security commitments regionally, nationally, and locally as illustrated in the modified theory of change (Fig. 6.1). I acknowledge that while food and nutritional insecurity (or insecure Food Security and Nutrition (FSN) as defined by HLPE, 2020) may be influenced by diverse and complex factors, it can be alleviated by improving availability, access, agency, utilization, stability and sustainability pillars of food and nutrition security (Bennett *et al.*, 2021a; HLPE, 2020; FAO, 2022b; Manlosa, 2022). The modified theory of change framework provides a summary of where the findings of this thesis may be applied to support efforts to achieve food and nutrition security using fish food systems.

To begin with, on recognizing the need for radical transformation of food systems (critical policy element 1), this thesis considers how the determinants of food and nutrition security (e.g. status of fish supply, role of different market actors, mechanisms of access, conditions for agency, sociodemographics and fish consumption patterns) could be incorporated into management and governance to support stability and sustainability and support food system change (FAO, 2022b). Second, to view food security and nutrition as a system interconnected with other systems and sectors (critical policy element 2), this thesis used an interdisciplinary approach to identify policy levers that cut across multiple sectors in the food system spanning fisheries, trade, public health, and governance aimed at achieving zero hunger. This aligns with the need to have a holistic or multi-sectoral approach to deliver on food and nutrition security (FAO, 2022b). Third, the focus on hunger and malnutrition (critical policy element 3) emerges in all the research chapters indicating the need to leverage policy by considering which factors among those revealed in this study may be addressed in the short-term, medium-term, and long-term to achieve food and nutrition security. Situated in this United Nation decade of action on nutrition, improving food system conditions that address hunger and malnutrition, for example, through incorporating fish, is highly advocated for (Farmery *et al.*, 2021; Golden *et al.*, 2021; Cai and Leung, 2022; Pounds *et al.*, 2022). Fourth, recognizing food security and nutrition as being context-specific and requiring diverse solutions (critical policy element 4) is evidenced in the thesis as I transition my investigations and analyses from global narratives to national contexts, then proceed to subnational, community and household levels. Finally, I present where the recommendations made in this thesis (Table 6.1) fit into the six interconnected pillars of food and nutrition security. For example, targeting the most vulnerable with the available fish supplies could maximize benefits when availability is insufficient for the whole population. This theory of change modification aligns with the need for empirical evidence across science-policy-practice interfaces, such as the global implementation of SDG-2, other SDGs, and various commitments on tackling malnutrition and food insecurities to ensure that inequities are addressed (FAO, IFAD, UNICEF, WFP and WHO, 2022). Considered together, these five pathways create enabling conditions for food system governance and research (critical policy element 5). This thesis argues for greater recognition of the determinants of food and nutrition security, across the six pillars, in fisheries management and governance in Kenya to support the achievement of nutrition security commitments such as the SDG 2 and other targets.

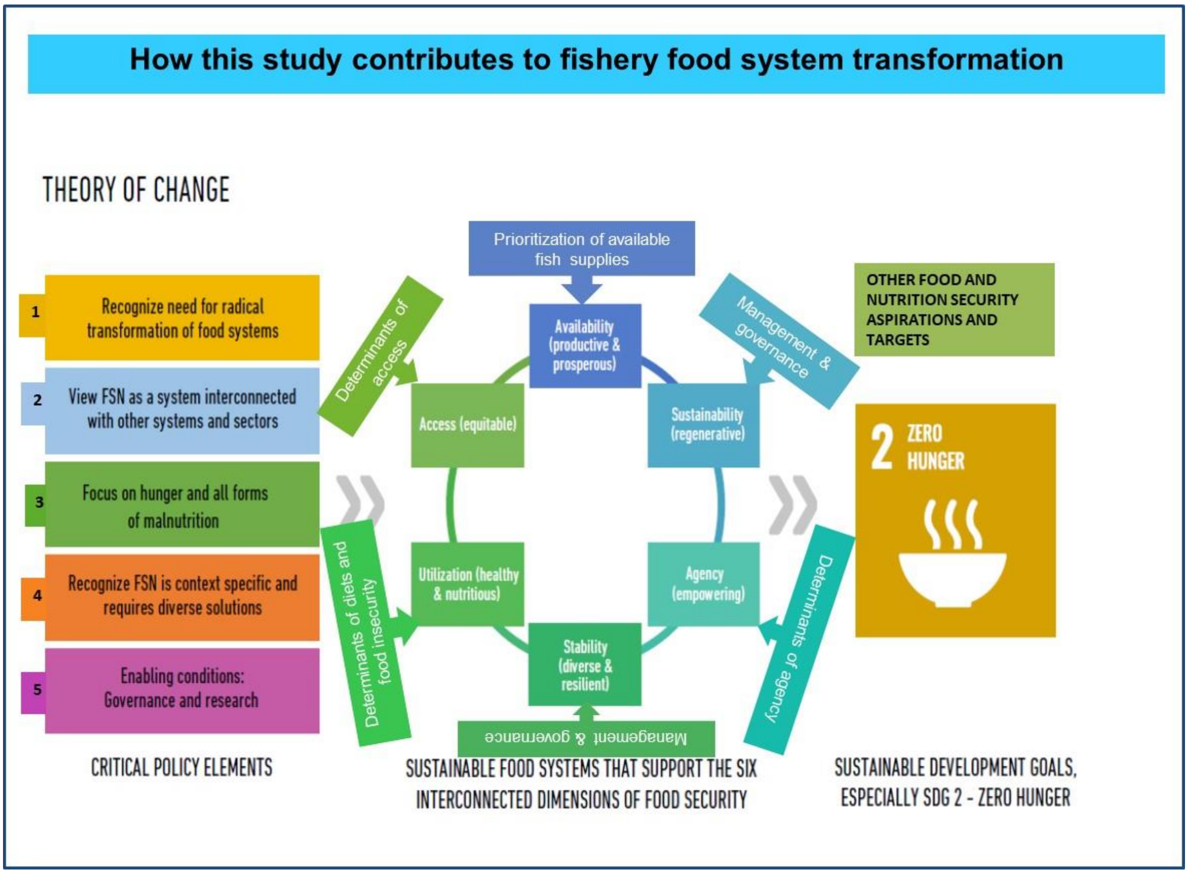


Figure 6.1 The modified theory of change indicating where to leverage the unraveled determinants of food and nutrition security from tropical small-scale fish food system in Kenya (Modified with permission from the Food and Agriculture Organization of the United Nations)

6.2 Conclusions and future research directions

In this thesis, I sought to answer the question of what influences people's uptake of fish and how this can best support food and nutrition security. I found that tropical small-scale fisheries hold great potential in alleviating nutrient deficiencies ("hidden hunger") when strategically targeted for use by the most in need or the most vulnerable. However, this requires a reframing of food security policies to incorporate fish as a diverse, nutritious, safe, and affordable food. There is a need to incorporate a better understanding of the determinants of food and nutrition security into food and fisheries policy. The attainment of food and nutrition security remains a complex endeavor as it entails multiple actors and will require holistic approaches. The various levers for policy considerations that have been identified and fitted in the modified theory of change are key pointers to where the transformation of aquatic food systems in Kenya may be promising. Incorporating the small-scale fish food system ("forgotten food" in policy and governance discourses) into Kenya's food and nutrition governance strategies and approaches can help in alleviating the complex challenge of nutritional deficiencies ("hidden hunger").

Further research is suggested to scale up the transformation of the small-scale fish food system through leveraging the factors influencing availability, access, agency, and utilization of fish in policy and governance that ensures stability and sustainability so that the attainment of nutrition security for all remains on course. This is a useful contribution considering the present debate of transforming food systems to attain food and nutrition security within the globally declared decade of action on nutrition by the United Nations. The findings of this PhD research could be of interest to the scholarly community, food security and nutrition practitioners, and policymakers and could inform future research agendas, policy dialogues, and practice interventions to ensure sustainable food and nutrition security pursuit. The need for further research is identified in three key areas: 1. to obtain empirical contextual information on fisheries nutrient profiles based on field collections of important food fish, especially from aquaculture 2. expand the number of micronutrients ("problem nutrients" that are lacking in target populations, such as iodine, Vitamin B12, and folate) that are quantified in fish, and 3. an assessment of intrahousehold food allocations and fish consumption practices to obtain individual-based health outcomes. This PhD thesis empirically demonstrates that targeting the fish food system in Kenya is an important and timely opportunity to deliver changes that are needed to have a transformed food system that supports food and nutrition security.

Appendix 1. Supplementary tables and figure for Chapter 2 - Contributions of food and nutrition security from fish

Table 2.2 Edible fish conversion percentages and multiplier factor for the fish and fish products extracted from the Kenya fisheries data sources

Fish and fish products	Edible proportion, %	Multiplier conversion factor	Reference
Finfishes	87	0.87	(Edwards *et al.*, 2019)
Crustaceans	38	0.38	(Edwards *et al.*, 2019)
Bivalve molluscs	17	0.17	(Edwards *et al.*, 2019)
Sea cucumbers	100	1	This study
Octopus, cuttlefish, squids	100	1	This study
Small finfishes (freshwater silver cyprinid, sardines, and anchovies)	100	1	This study
Exported fish products	100	1	This study
Imported fish products	100	1	(Thurstan and Roberts, 2014), This study

Table 2.3 Nutrient content of the 52 fish taxa reported in the most recent Fisheries Statistical Bulletin (sorted by their percentage abundance in supplied edible biomass)

No.	Family	Calcium (mg/100g)	Iron (mg/100g)	Selenium (µg/100g)	Zinc (mg/100g)	Vitamin A (µg/100g)	Total Omega-3 PUFA (g/100g)	Protein (g/100g)	% composition in edible biomass
1	Danionidae	837.00	3.37	32.30	2.78	82.20	0.59	18.00	31.32
2	Cichlidae	28.18	1.75	56.71	2.17	9.85	0.35	17.26	20.76
3	Latidae	134.00	1.74	196.00	0.94	13.90	0.30	20.00	17.28
4	Mixed freshwater species	134.82	1.54	75.34	1.58	23.26	0.42	17.35	7.37
5	Clariidae	45.45	1.23	87.15	0.83	26.50	0.21	17.10	3.53
6	Scombridae	90.70	2.55	63.45	0.81	24.68	0.44	22.15	3.41
7	Belonidae	48.93	0.71	46.95	0.91	226.33	0.26	17.25	1.64
8	Cyprinidae	113.82	0.83	28.88	1.16	19.46	0.62	17.89	1.45
9	Siganidae	33.30	0.81	15.72	1.33	27.70	0.21	18.97	1.42
10	Lutjanidae	29.73	0.42	56.38	0.63	138.37	0.22	18.31	1.03
11	Octopodidae	126.10	4.79	57.83	1.97	45.18	0.41	15.54	0.98
12	Lethrinidae	48.19	0.86	50.21	1.97	30.24	0.16	19.96	0.81
13	Scaridae	38.66	0.75	28.41	2.12	22.98	0.10	18.75	0.75
14	Clupeidae	292.00	2.04	95.78	1.72	29.42	0.41	20.05	0.75
15	Mixed demersal	99.99	0.88	38.06	1.50	67.48	0.23	18.48	0.74
16	Carangidae	63.86	1.09	37.79	0.83	60.79	0.27	19.50	0.72

No.	Family	Calcium (mg/100g)	Iron (mg/100g)	Selenium (µg/100g)	Zinc (mg/100g)	Vitamin A (µg/100g)	Total Omega-3 PUFA (g/100g)	Protein (g/100g)	% composition in edible biomass
17	Protopteridae	44.00	0.72	73.60	0.95	22.90	0.22	3.87	0.66
18	Sharks &Rays	16.02	0.68	36.14	0.61	31.31	0.27	20.54	0.58
19	Hemiramphidae	79.50	1.31	21.90	1.40	34.30	0.33	18.30	0.52
20	Sphyraenidae	34.58	0.56	31.70	0.60	24.15	0.23	19.88	0.43
21	Xiphiidae	9.57	0.26	43.40	0.46	5.94	0.32	19.70	0.40
22	Engraulidae	321.86	1.84	41.67	2.09	25.13	0.86	18.60	0.31
23	Loliginidae	126.10	4.79	57.83	1.97	9.96	0.41	15.54	0.29
24	Serranidae	54.46	0.62	38.33	1.16	152.15	0.17	18.40	0.29
25	Mugilidae	182.33	3.22	74.97	2.12	12.48	0.64	18.03	0.29
26	Alestidae	139.00	2.19	66.83	1.96	12.73	0.33	18.63	0.25
27	Haemulidae	36.86	0.57	41.37	1.04	63.98	0.18	19.14	0.25
28	Palinuridae	109.43	1.59	48.30	1.79	5.10	0.29	20.24	0.21
29	Acanthuridae	46.93	0.63	26.38	1.54	28.82	0.13	18.68	0.19
30	Nemipteridae	191.66	0.88	42.71	1.05	33.40	0.22	18.68	0.18
31	Mullidae	70.37	0.60	52.30	0.90	188.75	0.26	17.71	0.16
32	Chirocentridae	67.95	0.78	61.40	0.94	54.80	0.29	19.60	0.16
33	Istiophoridae	29.26	1.18	49.92	0.45	5.20	0.26	20.00	0.14
34	Mixed pelagic	81.94	0.99	45.86	1.03	87.35	0.28	19.07	0.14
35	Salmonidae	69.43	1.21	360.23	0.83	5.92	1.42	19.17	0.13

No.	Family	Calcium (mg/100g)	Iron (mg/100g)	Selenium (µg/100g)	Zinc (mg/100g)	Vitamin A (µg/100g)	Total Omega-3 PUFA (g/100g)	Protein (g/100g)	% composition in edible biomass
36	Penaeidae	109.43	1.59	48.30	1.79	54.00	0.29	20.24	0.12
37	Portunidae	109.43	1.59	48.30	1.79	1.52	0.29	20.24	0.10
38	Bivalve molluscs	149.43	8.53	61.00	2.04	81.00	0.31	9.88	0.09
39	Sepiidae	126.10	4.79	57.83	1.97	112.59	0.41	15.54	0.05
40	Sharks	16.02	0.68	36.14	0.61	31.31	0.27	20.54	0.04
41	Scyllaridae	109.43	1.59	48.30	1.79	5.10	0.29	20.24	0.01
42	Holothuridae	126.10	4.79	57.83	1.97	93.00	0.33	16.62	0.01
43	Sciaenidae	89.24	1.25	37.05	0.92	24.31	0.37	19.10	0.01
44	Gempylidae	16.62	0.47	40.39	0.40	14.24	0.24	17.98	0.01
45	Centrarchidae	62.00	1.48	37.30	1.09	15.40	0.40	18.90	0.01
46	Frozen mixed fish and fish products	92.43	0.93	41.28	1.30	75.68	0.25	18.72	0.01
47	Sparidae	102.00	0.86	66.30	0.95	9.83	0.43	17.90	0.00
48	Coryphaenidae	82.40	2.59	52.60	0.71	2.94	0.56	19.00	0.00
49	Bothidae	72.02	0.54	30.38	0.95	80.28	0.14	18.12	0.00
50	Trichiuridae	126.00	1.71	169.00	1.14	3.07	0.45	18.40	0.00
51	Soleidae	63.00	0.56	29.20	1.10	66.70	0.09	19.30	0.00
52	Paralichthyidae	124.00	0.87	53.30	0.93	47.00	0.37	15.70	0.00

Table 2.4 Average recommended nutrient intakes (RNI) for micronutrients, adequate intakes (AI) for proteins in children below 5 years, Source: (FAO, 2010; FAO/WHO, 2004; Institute of Medicine, 2006)

Ages	**Calcium (mg/day)**	**Iron (mg/day)**	**Selenium µg/day)**	**Zinc (mg/day)**	**Vitamin A (µgRE/day) Recom safe intake**	**Total Omega-3 PUFA (g/day)**	**Protein (g/day)**
0 - 1	400.0	5.1	11.0	3.7	391.7	0.6	11.0
1 - 2	400.0	5.1	11.0	3.7	391.7	0.6	11.0
2 - 3	600.0	4.7	20.0	4.8	450.0	0.8	16.0
3 - 4	600.0	4.7	20.0	4.8	450.0	0.8	16.0
4 - 5	600.0	4.7	20.0	4.8	450.0	0.8	16.0
Average	520.0	4.8	16.4	4.4	426.7	0.7	14.0

Table 2.5 Significant correlation associations of the fish nutrient content on the three PCA axes representing the three nutrient content patterns

Nutrients	**Correlation coefficient**	**p-value**
a. PCA 1 (32.3%) – Nutrient content pattern 1		
Iron	0.77	< 0.0001
Zinc	0.75	< 0.0001
Calcium	0.72	< 0.0001
Total Omega-3 PUFA	0.6	< 0.0001
Selenium	0.32	< 0.05
Protein	-0.33	< 0.05
b. PCA 2 (24.5%) – Nutrient content pattern 2		
Selenium	0.78	< 0.0001
Total Omega-3 PUFA	0.68	< 0.0001
Protein	0.36	< 0.0001
Iron	-0.28	< 0.05
Zinc	-0.38	< 0.01
Vitamin A	-0.51	< 0.001
c. PCA 3 (15.6%) – Nutrient content pattern 3		
Protein	0.75	<0.0001
Calcium	0.41	<0.01

Zinc	0.31	<0.05
Vitamin A	-0.31	<0.05
Selenium	-0.35	<0.05

Table 2.6 The average fish portion size by main fish taxa within each fish supply system that would fulfill 33.3% of recommended nutrient intakes across six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 fatty acids) for children below five years old. Fish taxa are ordered from most abundant within each system for the top 10 except aquaculture which has four species

Fish supply sources	Fish taxa	Portion size (g) to meet 33.3% RNI across 6 nutrients
Aquaculture systems	Cichlidae	83
	Clariidae	106
	Cyprinidae	122
	Salmonidae	78
Coastal and marine systems	Siganidae	108
	Lethrinidae	99
	Scombridae	80
	Lutjanidae	104
	Belonidae	86
	Scaridae	105
	Carangidae	98
	Octopodidae	59
	Sharks &Rays	113
	Clupeidae	66
Inland freshwater systems	Danionidae	46
	Latidae	88
	Cichlidae	82
	Clariidae	106
	Protopteridae	111
	Cyprinidae	74
	Alestidae	78
	Distichodontidae	64
	Mochokidae	76

	Bagridae	97
Imports	Scombridae	79
	Cichlidae	82
	Clupeidae	59
	Pangasiidae	99
	Frozen mixed fish and fish products	91
	Synodontidae	114
	Mugilidae	58
	Salmonidae	86
	Arripidae	71
	Others_imports	91
Average portion size	Inland freshwater systems	66
	Imports	80
	Aquaculture systems	89
	Coastal and marine systems	93

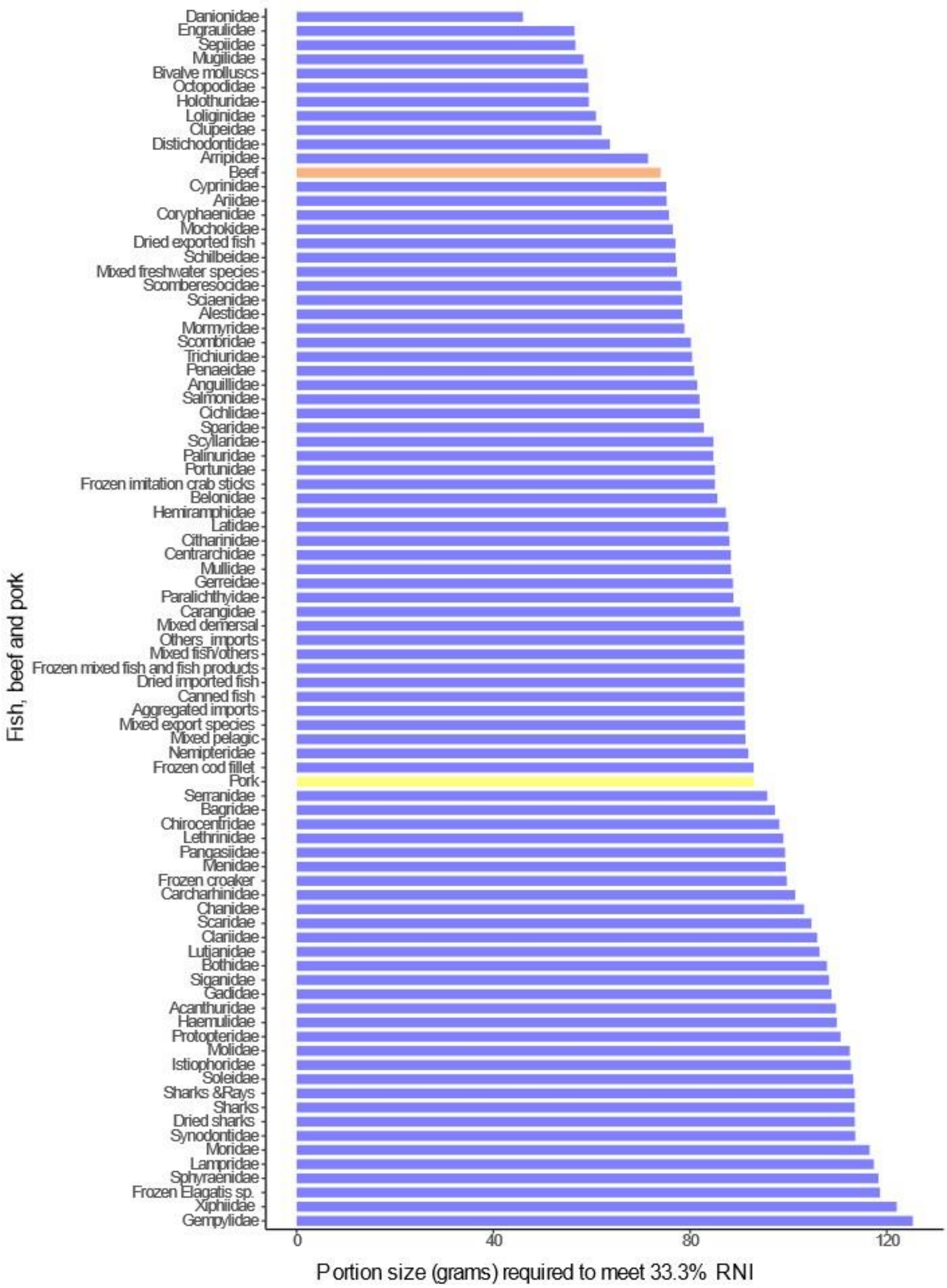


Figure S2.1 - The fish portion size (grams) required to reach an average of 33.3% of daily recommended nutrient intakes across six nutrients (calcium, iron, selenium, vitamin A, zinc, and omega-3 fatty acids) for all 84 fish taxa (2005-2020) reported in Kenya's statistical bulletins, and the equivalent values for beef (orange bar), pork (yellow bar) and chicken (red bar) taken from Tacon and Metian, 2013. The recommended intakes (RNI) are for children under 5 years old

Appendix 2. Table for Chapter 3 – Fish markets facilitate food and nutrition security in coastal Kenya: empirical evidence for policy leveraging

Table 3.5 All the traded fish taxa, their corresponding portion sizes required to meet 33.3% RNI for children under five years across 6 nutrients, and the portion price in Kenya Shillings and USD (1 KES ~ USD 0.0067)

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
Women small-scale traders	Acanthuridae	109	27	0.18
	Ariidae	75	26	0.17
	Belonidae	86	32	0.21
	Caesionidae	101	33	0.22
	Carangidae	95	32	0.21
	Chirocentridae	98	26	0.17
	Cichlidae	81	36	0.24
	Clariidae	104	36	0.24
	Clupeidae	59	21	0.14
	Coryphaenidae	76	24	0.16
	Danionidae	46	16	0.11
	Dasyatidae	119	30	0.20
	Engraulidae	56	20	0.13
	Haemulidae	110	35	0.23
	Hemiramphidae	87	26	0.17
	Istiophoridae	113	37	0.25
	Kyphosidae	127	32	0.21
	Labridae	93	40	0.27
	Latidae	88	49	0.33
	Lethrinidae	99	37	0.25

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Loliginidae	61	15	0.10
	Lutjanidae	104	33	0.22
	Mixed small marine species	92	44	0.29
	Mugilidae	58	17	0.11
	Muraenidae	110	33	0.22
	Myliobatidae	100	27	0.18
	Octopodidae	59	21	0.14
	Others	91	25	0.17
	Others-marine dried	91	41	0.27
	Penaeidae	81	46	0.31
	Scaridae	105	34	0.23
	Sciaenidae	76	23	0.15
	Scombridae	78	28	0.19
	Sharks	113	43	0.29
	Siganidae	108	38	0.25
	Sparidae	97	34	0.23
	Sphyraenidae	118	42	0.28
	Trichiuridae	80	24	0.16
Fish shop traders	Ariidae	75	26	0.17
	Belonidae	86	33	0.22
	Caesionidae	101	20	0.13
	Carangidae	93	34	0.23
	Cichlidae	81	18	0.12
	Clupeidae	59	12	0.08
	Coryphaenidae	76	21	0.14
	Danionidae	46	16	0.11

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Dasyatidae	119	33	0.22
	Haemulidae	110	29	0.19
	Hemiramphidae	87	17	0.11
	Istiophoridae	113	46	0.31
	Latidae	88	35	0.23
	Lethrinidae	99	32	0.21
	Lobotidae	81	24	0.16
	Loliginidae	61	29	0.19
	Lutjanidae	104	37	0.25
	Mixed small marine species	92	21	0.14
	Mugilidae	58	15	0.10
	Mullidae	88	19	0.13
	Myliobatidae	100	35	0.23
	Octopodidae	59	20	0.13
	Ostreidae	59	24	0.16
	Others	91	28	0.19
	Rachycentridae	109	33	0.22
	Scaridae	105	27	0.18
	Sciaenidae	76	16	0.11
	Scombridae	83	30	0.20
	Serranidae	96	33	0.22
	Sharks	113	40	0.27
	Siganidae	108	36	0.24
	Sparidae	97	34	0.23
	Sphyraenidae	118	40	0.27
	Terapontidae	78	23	0.15

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Trichiuridae	80	16	0.11
Men small-scale traders	Acanthuridae	113	34	0.23
	Ariidae	75	19	0.13
	Belonidae	86	25	0.17
	Caesionidae	101	31	0.21
	Carangidae	93	33	0.22
	Chirocentridae	98	25	0.17
	Cichlidae	81	15	0.10
	Clupeidae	59	15	0.10
	Coryphaenidae	76	30	0.20
	Danionidae	46	16	0.11
	Haemulidae	110	24	0.16
	Hemiramphidae	87	30	0.20
	Istiophoridae	113	48	0.32
	Labridae	93	27	0.18
	Lethrinidae	99	36	0.24
	Lobotidae	81	28	0.19
	Loliginidae	61	23	0.15
	Lutjanidae	104	40	0.27
	Mixed small marine species	92	23	0.15
	Mugilidae	58	12	0.08
	Mullidae	88	25	0.17
	Myliobatidae	100	20	0.13
	Octopodidae	59	21	0.14
	Others	91	24	0.16
	Rachycentridae	109	44	0.29

Fish market traders	Traded fish taxa	Portion size, g required to meet 33.3% RNI across 6 nutrients	Portion price, KES	Portion price, USD
	Scaridae	105	32	0.21
	Sciaenidae	76	21	0.14
	Scombridae	82	29	0.19
	Sharks	113	42	0.28
	Siganidae	108	40	0.27
	Sphyraenidae	118	30	0.20
Middlemen/Dealers	Acanthuridae	109	33	0.22
	Ariidae	75	13	0.09
	Carangidae	94	33	0.22
	Cichlidae	81	12	0.08
	Dasyatidae	119	21	0.14
	Haemulidae	110	20	0.13
	Lethrinidae	99	36	0.24
	Lobotidae	81	17	0.11
	Loliginidae	61	29	0.19
	Lutjanidae	104	35	0.23
	Octopodidae	59	24	0.16
	Portunidae	85	43	0.29
	Scaridae	105	31	0.21
	Sciaenidae	76	17	0.11
	Scombridae	80	29	0.19
	Serranidae	96	29	0.19
	Sharks	113	33	0.22
	Siganidae	108	33	0.22
	Sphyraenidae	118	41	0.27

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