Incorporating Biodiversity into Food Systems Modeling: Fisheries-Nutrition Linkages in Ghana

by

Zachary P. Gersten

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Nutritional Sciences)
in the University of Michigan
2023

Doctoral Committee:

Associate Professor Andrew D. Jones, Chair
Associate Professor Ana Baylin
Research Assistant Professor Erica C. Jansen
Dr. Daniel B. Sarpong, University of Ghana

Zachary P. Gersten

zgersten@umich.edu

ORCID iD: 0000-0001-8328-0199

Acknowledgements

I would like to thank my loved ones for supporting me in my endeavors. I am grateful to my advisor, Dr. Andy Jones, for shepherding me throughout the doctoral program, and my dissertation committee, Dr. Ana Baylin, Dr. Erica Jansen, and Dr. Daniel Bruce Sarpong, for their time, energy, and expertise.

I would also like to thank Mary Nana Anima Akrofi, Ebenezer Amaquandoh, Emma Adom, and Aziz Adams for their research assistance, as well as the people who agreed to participate in our study and share their wealth of knowledge.

I also wish to acknowledge the organizations who funded this dissertation research: the University of Michigan (UM) International Institute, the UM Rackham Graduate School, the UM Department of Nutritional Sciences in the School of Public Health, and the UM Graham Sustainability Institute's Dow Sustainability Fellows Program.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AIDS	Almost ideal demand system
ECBAS	Ethics Committee for Basic and Applied Sciences
GLSS	Ghana Living Standards Survey
FAFH	Food away from home
IRB	Institutional review board
IMR	Inverse Mills Ratio
LMIC	Low- and middle-income country
MDD-W	Minimum diet diversity for women
MoFAD	Ministry of Fisheries and Aquaculture Development
PAH	Polycyclic aromatic hydrocarbons
PCA	Principal component analysis
QUAIDS	Quadratic almost ideal demand system
UM	University of Michigan

Abstract

Food systems in low- and middle-income countries are rapidly transforming due to population growth, urbanization, rising consumer incomes, and changes to built and natural environments. These trends are associated with a triple burden of malnutrition, that is, concurrent undernourishment, micronutrient deficiencies, and overnutrition. Previous research has established the critical role of fish and seafood in healthy diets by contributing animal protein, omega-3 polyunsaturated fatty acids, and micronutrients, including vitamin A, calcium, iron, zinc, and iodine. In Ghana, the country focus of this dissertation, fish and seafood represents nearly 70% of all protein-rich food expenditures. However, fish and seafood consumption and its nutrient composition can vary based on biodiversity factors, such as species/genera (e.g., mackerel versus tilapia or crab) or production sources (e.g., marine or freshwater; wild capture or farmed). These variations are relatively underexplored as nutrition research often ignores biodiversity by combining species/genera and production sources into a single fish and seafood group. This dissertation research uses primary qualitative data and secondary data collected in 2016-17 as part of the seventh round of the Ghana Living Standards Survey (GLSS 7) to improve our understanding of fish and seafood biodiversity in the food system and its influence on consumer behaviors.

Aim 1 is a qualitative study that characterizes the fish and seafood consumption behaviors of women living in Accra, Ghana and assesses how biodiversity in the food system impacts them. Using thematic analysis, we interpolated four interrelated themes that link their

consumption behaviors to the greater food system ('tastes and preferences', 'health and nutrition', 'social, cultural, and religious factors', and 'cost and convenience'). The sample reported consuming 22 fish and seafood species/genera in traditional soups and stews, which were generally perceived as beneficial to health and nutrition and worth the premium over other protein-rich foods. However, there were widespread concerns about marine and freshwater sources related to climate change, imports, and illegal fishing practices.

Aim 2 assesses the contribution of fish and seafood species/genera to dominant patterns of food purchasing behaviors in Ghana. We generated these patterns by applying principal component analysis to nationally representative household food expenditure data from the GLSS 7. Then, we used multivariable regression analysis to assess the cross-sectional associations between those patterns and socioeconomic status. We found that freshwater fish species/genera were correlated with starchy staples, fruits, and vegetables in the ‘traditional’ pattern, which was associated with lower socioeconomic status. Marine fish species were correlated with refined cereal and grain products, dairy, and packaged beverages in the ‘modern’ food pattern, which was associated with higher socioeconomic status.

Aim 3 assesses consumer demand for fish and seafood species/genera by estimating household responses to income and food price changes. We used household expenditure data from the GLSS 7 to specify a censored Quadratic Almost Ideal Demand System (QUAIDS) model. Then, we used the model outputs to derive the income and own- and cross-price elasticities of demand for each fish and seafood species/genera. Our findings confirm that fish and seafood is inelastic to income and price changes, but we observed heterogeneity in consumer responses by species/genera.

In sum, this dissertation supports that biodiversity influences consumption behaviors for fish and seafood in Ghana. Policymakers and practitioners can use this research to design and implement food systems interventions that harness fish and seafood for nutrition goals.

Chapter 1 Introduction

1.1 Food systems in low- and middle-income countries

Food systems represent the network of actors, activities, and conditions that impact the foods we eat (1). They are generally conceived to encompass food production, processing, distribution, consumption, and waste (2) and span natural and anthropogenic boundaries across socioecological levels (3). By embracing these complexities, food systems research moves beyond linear thinking (i.e., a food chain), to contest with the synergies and tradeoffs that occur when inputs, outputs, and moderating factors interact (4). In low- and middle-income countries (LMICs), food systems are generally conceived to comprise smallholder producers and homestead farms that sell or trade fruits, vegetables, staple cereals, grains, and tubers, and livestock in local or regional markets (5). Yet, food systems in these settings are rapidly transforming (1,6) due to drivers like population growth, urbanization, rising consumer incomes, and changes to the natural and built environment (7). For example, by 2050, Africa's urban population is expected to nearly triple by adding one billion people (8), which will tilt food environments toward high processed foods consumed away from home (7). Higher incomes and commensurately higher meat consumption (9,10) also increase demand for livestock products which in turn incentivizes agriculture to increase livestock production (11). Finally, as food manufacturing and distribution in LMICs have shifted toward conglomeration (12), consumer demand for purchased and processed foods has grown (13).

This food system transformation is tied to different malnutrition outcomes (13). In the nutrition transition, which was first conceived by Barry Popkin, the predominant diets of societies change along economic and demographic trends, such as rising inequality (14). The three stages, or patterns, of the nutrition transition that are most relevant to the food system changes occurring in LMICs are ‘Famine’, ‘Receding famine’, and ‘Degenerative diseases’. In the ‘Famine’ stage, diets are monotonous and composed of cereals, grains, and starches, which are associated with undernourishment and micronutrient deficiencies, especially amongst women and children. The next stage, ‘Receding famine’, sees changes to monotonous diets including more fruits and vegetables and animal source foods. Then, in ‘Degenerative diseases’, the predominant diet continues to diversify, but relies on highly processed foods. In this stage, overnutrition-related outcomes, such as obesity, begin to emerge. There is a robust body of literature that has studied the nutrition transition globally (15) and across diverse contexts, including Sub-Saharan Africa (16,17), the Middle East and North Africa (18–20), South Asia (21–23), and Latin America (24,25).

Food systems that are transitioning between these stages are often characterized by the triple burden of malnutrition, or undernourishment, micronutrient deficiencies, and overnutrition occurring at the same time (26–29). Ghana, the country focus of this dissertation research, is a lower-middle-income country whose food system is undergoing significant transformation (30,31). Agriculture remains an important livelihood, yet the agricultural labor force is sharply decreasing (32) and the proportion of households who own or operate farms declined from 51.5% in 2012/13 to 44.1% in 2016/17 (33,34). Ghana’s urban population continues to grow from 50.9% in 2010 to 56.7% in 2021 (35,36). Household poverty rates have overall decreased from 31.9% in 2005/06 to 23.4% in 2016/17, though inequality, as measured using the Gini index, has slightly increased (37,38). The impacts of these drivers are observable in the food retail environment: high-income consumers might patron new supermarkets that are opening in large urban centers (39), while low- and middle-income consumers prefer traditional open-air markets (40).

Ghana is also experiencing the triple burden of malnutrition (41). A meta-analysis estimated that the national prevalence of obesity has increased over the past 20 years to 17.1%, with higher rates in women than men (21.9% and 6.0%, respectively) and for urban dwellers than rural (20.6% and 8.0%, respectively) (42). Undernutrition persists, especially among children aged under 5 years. One study analyzing data from the 2011 Multiple Indicator Cluster Survey found that the prevalence of stunting, wasting, and underweight was 22.7%, 6.2%, and 13.4%, respectively (43). Another study using the 2014 Ghana Demographic and Health Survey estimated those indicators at 18.4%, 5.3%, and 10.4% (44). Finally, the prevalence of micronutrient deficiencies among vulnerable populations is high. The 2017 Ghana Micronutrient Survey reported that over one-fifth of children under 5 years were iron deficient (45).

Policies and interventions that target food systems in transition could be powerful tools for addressing many types of malnutrition (6). However, the complex, multisectoral nature of food systems makes designing comprehensive policies and interventions difficult (3). One dimension that could be useful for understanding the nature of food systems transformation across multiple components is biodiversity, which describes the variety of species in a given space. Biodiversity principles have already been applied in research on natural environments, food production, and diets, but rarely in research that assesses linkages between food system components.

1.2 The role of biodiversity in low- and middle-income country food systems

Biodiversity is a key principle for working ecosystems (46). There are many definitions of biodiversity built for different purposes. In its simplest conception, biodiversity is measured by species richness, or the number of species present in a given space (46,47). More informational metrics can weigh species richness by population sizes or prioritize key species with important ecosystem functions (46). Biodiversity can also be measured across varying scales, such as the amount of genetic variation within one species. Biodiversity is generally believed to improve ecosystem resilience, or the ability of an ecosystem to rebound after some perturbation (48,49). One way is that many species covering essential ecosystem functions will work in synchrony to return the ecosystem to a balanced state. Another way is many species serving one functional role, thereby ensuring the survival of that function in the case that some species are eliminated.

Biodiversity is also important to food systems by supporting essential functions (50). For example, biodiversity directly supports human diets, as we consume many foods that originate from different species. Biodiversity can also support food production by engineering ecosystem resources and processes, like water supply, soil fertility, pollination, and pest control (51). We can apply the same concept of ecosystem resilience to a food system: enough species covering essential food system functions can ensure its survival when perturbations occur (48). However, food systems are a major driver of biodiversity loss (51), as land clearing for crops and livestock can destroy natural habitats; fertilizers and pesticides can pollute soil and water (e.g., via eutrophication) and disrupt food webs (52,53); and unsustainable extraction of natural resources, such as overfishing, can deplete species stocks (54). Aquatic biodiversity, which is explored in this dissertation, is impacted by fisheries and aquaculture, among other activities (51). In addition to overfishing, wild capture fishing can harm biodiversity by extracting nontargeted species (i.e., bycatch), fishing gears destroying habitats, or directly injuring organisms (54). Aquaculture, on the other hand, can introduce invasive species, pollute surrounding ecosystems, contribute to habitat loss by converting coastal ecosystems into farming areas, and introduce parasite and infectious diseases, among others (55). Food systems also contribute over one-third of global greenhouse gas emissions (56), thereby driving climate change and causing further biodiversity loss (57).

Biodiversity is of particular importance for low- and middle-income countries in different stages of the nutrition transition. There, foraging and agricultural communities consume wild and cultivated plant and animal species to supplement their generally monotonous diets (58,59). In a systematic review by Jones (2017), 19 of the 21 studies that were assessed reported small positive associations between agricultural biodiversity and diet diversity (60), a measure that is associated with socioeconomic status (61) and nutrient adequacy (61–63). While diet diversity focuses on food groups rather than species, a cross-sectional study by Lachat et al. (2017) found that when paired with dietary species richness, the two measures together performed well in identifying nutrient adequate diets (64). Biodiversity is also evident in integrated agriculture-aquaculture (IAA) systems (65). In these, agricultural outputs, like crop residues, livestock manure, and night soil, are fed to the fish and other aquatic organisms being cultivated (66). Then, the outputs of aquaculture (i.e., 'pond muck') are collected and used as a crop fertilizer (67). As the nutrition transition continues, consumers tend toward consuming more highly processed foods (14). While these foods might increase overall diet diversity (68), biodiversity in the food system will diminish as diets coalesce around the same foods produced by fewer crops species (69). Since biodiversity hotspots are commonly located in LMICs (64,70), their biodiversity loss will be particularly pronounced (71).

In Ghana, past research on terrestrial biodiversity has focused on local knowledge, forest management, and resource conflicts (72), as well as spirituality (72–74). There is a small body of research documenting biodiversity as a source of wild foods (72,75) and proposing neglected and underutilized crops as nutrition sources in sustainable food systems (76,77). Ghana stands out as biodiversity hotspot for traditional African vegetables (78), but its biodiversity is threatened by cocoa land expansion and timber production, whose intensification was incentivized by structural adjustment programs in the 1960s and 70s (79).

In Ghana, many fish and seafood species/genera, including mackerel, herring, anchovies, sea bream, barracuda, redfish, tuna, tilapia, catfish, crab, shrimp, lobster, and snails, are essential to Ghanaian diets, as they are highly consumed year-round (80) and represent the majority of animal protein consumed (81). However, Ghana's increasing demand for fish and seafood threatens its wealth of aquatic biodiversity (82), which also includes birds, mammals, and invertebrates (83). Poor fisheries management enabled overfishing, which has depleted the stocks of marine forage fish (mackerel, herring, and anchovy) in the Gulf of Guinea (84,85). These forage fish are the foundation of healthy marine ecosystems, as they are the conduit through which energy is transferred from primary producers like plankton to higher trophic level species that prey on them (86). To replenish these stocks, in 2019, the Government of Ghana began implementing annual fisheries closures during the July to August bumper fishing season to protect reproduction and conserve juvenile fish (87,88). Another set of national policies promote aquaculture production and demand for farmed fish. The Ghana National Aquaculture Development Plan (GNADP) aimed to scale up aquaculture production to 100,000 metric tonnes per year by financing research and developing infrastructure around Lake Volta (89–91). However, scaling aquaculture can conflict with sustainability goals, as increased farmed fish consumption can result in intensified aquaculture and negative environmental impacts (92).

1.3 Fish and seafood as a source of nutrition amidst food systems transformation

Fish and seafood are key components of healthy diets, and their consumption is increasing globally (93). In many coastal low- and middle-income countries, aquatic foods, including fish and seafood, contribute more than 20% of animal protein intake (93), as well as other essential nutrients, such as omega-3 polyunsaturated fatty acids (PUFAs) (94), iron, zinc, vitamin A, and iodine (95–97).

Fish and seafood biodiversity contributes to diets and promotes nutrition across the stages of the nutrition transition. In foraging societies, invertebrates, such as molluscs (e.g., clams and snails) or echinoderms (e.g., sea urchins and sea cucumbers), gleaned in tidal pools or at the seashore provide dietary nutrients that might be otherwise unattainable through other food sources (98,99). For the 'Famine' and 'Receding famine' stages, there is a robust literature that describes the nutrition potential for small indigenous fish species in lower-income settings, including in Sub-Saharan Africa (95,100–102) and South Asia (103–112). When consumed whole, including the eyes, skin, bones, and viscera, one to a few servings (100g) of these fish species could help individuals meet the recommended dietary allowances for vitamin A, calcium, iron, and zinc, even after taking sex and life stage into account (110). In the 'Degenerative diseases' stage, fish and seafood are generally viewed as components of healthy diets that prevent poor health outcomes related to overnutrition; they are recommended in food-based dietary guidelines (113), healthy eating indices (114–116), and as part of the Mediterranean Diet (117,118). As incomes rise, consumers might prefer larger and more expensive farmed fish like tilapia (119,120), of which only the flesh is consumed (121). These larger farmed species are much lower in vitamin A, calcium, iron, and zinc content (110), and their higher consumption in higher income populations is associated with lower micronutrient intake (103).

Ghana’s food-based dietary guidelines acknowledge the significant contribution of fish and seafood to animal protein intake, especially among urban populations. Further messaging promotes oily marine fish consumption and warns against larger fish to reduce cardiovascular disease risk and heavy metal exposure, respectively (122). Among highly consumed fish and seafood in Ghana, there is significant heterogeneity in their polyunsaturated fatty acid and micronutrient content, as evidenced in the FAO/INFOODS Food Composition Table for Western Africa (2019) (123). (See Table 1.1) Raw sardine has the highest levels of PUFAs, followed by canned anchovy, raw anchovy, raw mackerel, and raw North African catfish. Canned oily marine fish (anchovy, mackerel, and sardine) have the highest calcium and iron content, while raw crab is highest in zinc and vitamin A.

Empirical evidence in Ghana suggests an “inverse U” relationship between the household income and fish and seafood expenditure, such that middle-income consumers favor fish and seafood the most, while low- and high-income consumers prefer other foods (Ackah & Appleton, 2007). This general relationship is corroborated by studies using a range of research methods on smaller samples. Three studies observed the frequent consumption of fish and seafood in caregivers and their infants and children living in rural settings. In a qualitative study of infant and young child feeding in two food insecure communities in Northern and Central regions, Armar-Klemesu et al. (2018) reported that caregivers add dried powdered anchovies to vegetable stews and porridge to enrich their nutrient content (124). Colecraft et al. (2006) found that fish and seafood was universally consumed in a cross-sectional sample of mixed income caregivers from communities representing Ghana’s three agroecological zones (125). Bandoh & Kenu (2017) also found frequent fish and seafood consumption in a smaller cross-sectional sample of children aged under 5 years in a fishing community in Central region, observing that nearly 90%

of the sample consumed fish or shellfish in the last week (126). Two studies conducted in urban settings described aquatic biodiversity in fish and seafood consumption. In a one-year longitudinal study of households in Accra and Tamale (coastal and inland, respectively), Onumah et al. (2020) observed more than 12 fish and seafood species/genera consumed by the sample, and that households in Accra consumed more fresh fish but less smoked fish than households in Tamale (80). Then, in a pooled cross-sectional sample of four regional capitals, Mingle et al. (2021) observed that tilapia was most frequently consumed, followed by mackerel, tuna, snapper, and herring in that order (127). Finally, Akuffo et al., (2020) used probabilistic methods to characterize fish and seafood consumers by analyzing a subsample of the sixth round of Ghana Living Standards Survey (GLSS), a nationwide household survey. The results of the latent class model divided households into traditional and non-traditional classes, and the study found mixed associations between sociodemographic (age, gender, religion, ethnicity, education), economic (household income and food prices), and environmental factors (agroecology and month of the year) and fish and seafood expenditure (128).

In sum, previous research suggests that food systems transformation and the nutrition transition influence fish and seafood consumption in Ghana. While fish and seafood were overall highly consumed, consumer behaviors for species/genera appeared to differ by region, urban and rural strata, and household income. Because biodiversity was not rigorously assessed in any of the studies, we are limited in our ability to evaluate how these dynamic, societal forces impact fish and seafood access, consumer demand, and roles in healthy diets. Therefore, food systems research that incorporates biodiversity in its design and implementation is needed to understand variation in consumer behaviors for this important type of food.

1.4 Dissertation aims

The overall purpose of this dissertation is to describe consumer behaviors for fish and seafood species/genera in Ghana and characterize their relationships with the food system.

The first aim of this dissertation was to identify and characterize the fish and seafood consumer behaviors of women living in Accra, Ghana, assess their biodiversity, and understand how the food system impacts them. We used qualitative research methods to identify the fish and seafood consumer behaviors and their food system linkages by collecting detailed information on their consumption of fish and seafood species/genera and consumer perceptions of fisheries and aquaculture, food processing, market accessibility, food safety, culture and religion, tastes and preferences, and sustainability. Our analysis also examined whether socioeconomic context influenced the relationships between the food system and consumer behaviors. Where possible, we triangulated findings with information collected from individuals in key food systems roles, including members of the canoe fishermen's union, fish and seafood smokers, and market vendors. The findings of this qualitative study, presented in Chapter 2, enhance our understanding of consumer behaviors for fish and seafood species/genera in a rapidly transitioning LMIC food system and identify key leverage points for food system policies and interventions that use fish and seafood to target the triple burden of malnutrition.

The second aim of this dissertation was to assess the contribution of fish and seafood species/genera in dominant patterns of food purchasing behaviors in Ghana. We applied principal component analysis to nationally representative household expenditure data from the seventh round of the Ghana Living Standards Survey. Then, we used multivariable regression analysis to assess associations between household adherence to those patterns and potential sociodemographic, economic, and environmental determinants. In a sensitivity analysis, we disaggregated fish and seafood into species/genera to check whether food expenditure patterns and their associations with household determinants held. We hypothesized that ‘traditional’ and ‘modern’ food expenditure patterns would emerge and that fish and seafood would be significant components of both patterns; however, each pattern would be comprised of distinct species/genera. The findings of this aim, presented in Chapter 3, generate new insights on the types of foods that are purchased with fish and seafood species/genera on a national level, and the characteristics of households who associated with them.

The third aim of this dissertation was to assess consumer demand for fish and seafood species/genera and estimate household responses to income and food price changes. We used household expenditure data from the seventh round of the GLSS to specify a Quadratic Almost Ideal Demand System (QUAIDS) model, which accounted for the selection bias caused by zero expenditure on food items. Then, we derived the income and own- and cross-price elasticities of demand for each of the fish and seafood species/genera. The results of this aim, presented in Chapter 4, improve our understanding of consumer demand for fish and seafood in Ghana and provide benchmarks for estimating the consequences of market-oriented food system policies and interventions.

1.5 References

1. HLPE. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: Committee on World Food Security; 2017. Report No.: 12.

2. Berkum S van, Dengerink J, Ruben R. The food systems approach: sustainable solutions for a sufficient supply of healthy food. Vol. 538076. The Hague: Wageningen Economic Research; 2018.

3. Hospes O, Brons A. A systematic literature review. In: Food systems governance: challenges for justice, equality and human rights. Routledge; 2016.

4. Ericksen PJ. Conceptualizing food systems for global environmental change research. Global Environmental Change. 2008 Feb;18(1):234–45.

5. Béné C. Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. Food Sec. 2020 Aug;12(4):805–22.

6. Brouwer ID, McDermott J, Ruben R. Food systems everywhere: Improving relevance in practice. Global Food Security. 2020 Sep;26:100398.

7. Béné C, Prager SD, Achicanoy HAE, Toro PA, Lamotte L, Cedrez CB, et al. Understanding food systems drivers: A critical review of the literature. Global Food Security. 2019 Dec;23:149–59.

8. United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2018 Revision. New York: United Nations; 2019. Report No.: ST/ESA/SER.A/420.

9. Vranken L, Avermaete T, Petalios D, Mathijs E. Curbing global meat consumption: Emerging evidence of a second nutrition transition. Environmental Science & Policy. 2014 May;39:95–106.

10. Cole JR, McCoskey S. Does global meat consumption follow an environmental Kuznets curve? Sustainability: Science, Practice and Policy. 2013 Oct;9(2):26–36.

11. Godfray HCJ, Aveyard P, Garnett T, Hall JW, Key TJ, Lorimer J, et al. Meat consumption, health, and the environment. Science. 2018 Jul 20;361(6399):eaam5324.

12. Baker P, Machado P, Santos T, Sievert K, Backholer K, Hadjikakou M, et al. Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. Obesity Reviews [Internet]. 2020 Dec [cited 2023 Jul 10];21(12). Available from: https://onlinelibrary.wiley.com/doi/10.1111/obr.13126

13. Reardon T, Tschirley D, Liverpool-Tasie LSO, Awokuse T, Fanzo J, Minten B, et al. The processed food revolution in African food systems and the double burden of malnutrition. Global Food Security. 2021;28:100466.

14. Popkin BM. Nutritional Patterns and Transitions. Population and Development Review. 1993;19(1):138–57.

15. Van Hook J, Altman CE, Balistreri KS. Global patterns in overweight among children and mothers in less developed countries. Public Health Nutr. 2013 Apr;16(4):573–81.

16. Steyn NP, Mchiza ZJ. Obesity and the nutrition transition in Sub-Saharan Africa. Annals of the New York Academy of Sciences. 2014;1311(1):88–101.

17. Rousham EK, Pradeilles R, Akparibo R, Aryeetey R, Bash K, Booth A, et al. Dietary behaviours in the context of nutrition transition: a systematic review and meta-analyses in two African countries. Public Health Nutr. 2020 Aug;23(11):1948–64.

18. Zaghloul S, Al-Hooti SN, Al-Hamad N, Al-Zenki S, Alomirah H, Alayan I, et al. Evidence for nutrition transition in Kuwait: over-consumption of macronutrients and obesity. Public Health Nutr. 2013 Apr;16(4):596–607.

19. Belfki H, Ali SB, Aounallah-Skhiri H, Traissac P, Bougatef S, Maire B, et al. Prevalence and determinants of the metabolic syndrome among Tunisian adults: results of the Transition and Health Impact in North Africa (TAHINA) project. Public Health Nutr. 2013 Apr;16(4):582–90.

20. Madanat HN, Lindsay R, Campbell T. Young urban women and the nutrition transition in Jordan. Public Health Nutr. 2011 Apr;14(4):599–604.

21. Shetty PS. Nutrition transition in India. Public Health Nutr. 2002 Feb;5(1a):175–82.

22. Yagya Prasad Subedi, Debbi Marais, David Newlands. Where is Nepal in the nutrition transition? Asia Pacific Journal of Clinical Nutrition. 2017 Mar 1;26(2).

23. Griffiths PL, Bentley ME. The Nutrition Transition Is Underway in India. The Journal of Nutrition. 2001 Oct;131(10):2692–700.

24. Albala C, Vio F, Kain J, Uauy R. Nutrition transition in Chile: determinants and consequences. Public Health Nutr. 2002 Feb;5(1a):123–8.

25. Rivera JA, Barquera S, González-Cossío T, Olaiz G, Sepúlveda J. Nutrition Transition in Mexico and in Other Latin American Countries. Nutrition Reviews. 2004 Jul;62:S149–57.

26. Pinstrup-Andersen P. Agricultural research and policy for better health and nutrition in developing countries: a food systems approach: Agricultural research and policy for better health and nutrition in developing countries. Agricultural Economics. 2007 Dec 19;37:187–98.

27. Gómez MI, Barrett CB, Raney T, Pinstrup-Andersen P, Meerman J, Croppenstedt A, et al. Post-green revolution food systems and the triple burden of malnutrition. Food Policy. 2013 Oct;42:129–38.

28. Meenakshi JV. Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics. 2016 Nov;47(S1):115–34.

29. Christian AK, Dake FA. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: prevalence and influencing household factors. Public Health Nutr. 2022 Jun;25(6):1563–76.

30. Agyapong N, Annan R, Apprey C, Aryeetey R. A review of Ghana's food system and its implications on sustainability and the development of national food-based dietary guidelines. AJFAND. 2022 Apr 4;22(2):19525–82.

31. Fuseini I. "We Eat Every Day, but I'm Perpetually Hungry": Interrogating Food System Transformation and (Forced) Dietary Changes in Tamale, Ghana. In: Transforming Urban Food Systems in Secodnary Cities in Africa. Cham, Switzerland: Palgrave Macmillan; 2023.

32. Ecker O. Agricultural transformation and food and nutrition security in Ghana: Does farm production diversity (still) matter for household dietary diversity? Food Policy. 2018 Aug;79:271–82.

33. Ghana Statistical Service. Ghana Living Standards Survey round 6 (GLSS6), Main Report. Accra: Ghana Statistical Service; 2014.

34. Ghana Statistical Service. Ghana Living Standards Survey round 7 (GLSS7), Main Report [Internet]. Ghana Statistical Service. Accra: Ghana Statistical Service; 2019 p. 1–343. Available from: https://statsghana.gov.gh/gsspublications.php?category=MTAwMjg3Mzk3NC4zMDc=/webstats/1opr93rn57

35. Ghana Statistical Service. 2010 Population and Housing Census. Accra, Ghana; 2013.

36. Ghana Statistical Service. Population of Regions and Districts [Internet]. Ghana Statistical Service; 2021. (Ghana 2021 Population and Housing Census). Report No.: Volume 3A. Available from: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf

37. Molini V, Paci P. Poverty Reduction in Ghana: Progress and Challenges. Washington, D.C.: The World Bank; 2015.

38. Ghana Statistical Service. Ghana Living Standards Survey (GLSS7): Poverty trends in Ghana; 2005-2017. Ghana Statistical Service. 2018;14–21.

39. Andam KS, Tschirley D, Asante SB, Al-Hassan RM, Diao X. The transformation of urban food systems in Ghana: Findings from inventories of processed products. Outlook Agric. 2018 Sep;47(3):233–43.

40. Meng T, Florkowski WJ, Sarpong DB, Chinnan MS, Resurreccion AVA, Meng T, et al. Consumer's Food Shopping Choice in Ghana: Supermarket or Traditional Outlets? 2014 [cited 2023 Jun 23]; Available from: https://ageconsearch.umn.edu/record/164600

41. Mockshell J, Asante-Addo C, Andam KS, Asante F. Transitioning to nutrition-sensitive food environments in Ghana: Triple sector strategies to reduce the triple burden of malnutrition. 2021;52.

42. Ofori-Asenso R, Agyeman AA, Laar A, Boateng D. Overweight and obesity epidemic in Ghana - A systematic review and meta-analysis. BMC Public Health [Internet]. 2016;16(1). Available from: http://dx.doi.org/10.1186/s12889-016-3901-4

43. Welaga Miah R, Awingura Apanga P. Risk Factors for Undernutrition in Children under Five Years Old: Evidence from the 2011 Ghana Multiple Indicator Cluster Survey. J AIDS Clin Res [Internet]. 2016 [cited 2023 Jul 10];7(7). Available from: https://www.omicsonline.org/open-access/risk-factors-for-undernutrition-in-children-under-five-years-old-evidencefrom-the-2011-ghana-multiple-indicator-cluster-survey-2155-6113-1000585.php?aid=75644

44. Boah M, Azupogo F, Amporfro DA, Abada LA. The epidemiology of undernutrition and its determinants in children under five years in Ghana. Zereyesus Y, editor. PLoS ONE. 2019 Jul 31;14(7):e0219665.

45. University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-Wellcome Trust, UNICEF. Ghana Micronutrient Survey 2017. Accra, Ghana; 2017.

46. Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, Lavorel S, et al. EFFECTS OF BIODIVERSITY ON ECOSYSTEM FUNCTIONING: A CONSENSUS OF CURRENT KNOWLEDGE. Ecological Monographs. 2005 Feb;75(1):3–35.

47. Purvis A, Hector A. Getting the measure of biodiversity. Nature. 2000 May;405(6783):212–9.

48. Cottrell RS, Fleming A, Fulton EA, Nash KL, Watson RA, Blanchard JL. Considering land–sea interactions and trade-offs for food and biodiversity. Glob Change Biol. 2018 Feb;24(2):580–96.

49. Oliver TH, Heard MS, Isaac NJB, Roy DB, Procter D, Eigenbrod F, et al. Biodiversity and Resilience of Ecosystem Functions. Trends in Ecology & Evolution. 2015 Nov;30(11):673–84.

50. Dawson IK, Park SE, Attwood SJ, Jamnadass R, Powell W, Sunderland T, et al. Contributions of biodiversity to the sustainable intensification of food production. Global Food Security. 2019 Jun;21:23–37.

51. Benton TG, Bieg C, Harwatt H, Pudasaini R, Wellesley L. Food system impacts on biodiversity loss: three levers of food system transformation in support of nature [Internet]. London: Chatham House; 2021. Report No.: 208223. Available from: https://www.ciwf.com/media/7443948/food-system-impacts-on-biodiversity-loss-feb-2021.pdf

52. Tinker PB. The environmental implications of intensified land use in developing countries. Greenland DJ, Gregory PJ, Nye PH, editors. Phil Trans R Soc Lond B. 1997 Jul 29;352(1356):1023–33.

53. Brühl CA, Zaller JG. Biodiversity Decline as a Consequence of an Inappropriate Environmental Risk Assessment of Pesticides. Front Environ Sci. 2019 Oct 31;7:177.

54. Rice JC, Ridgeway L. Conservation of Biodiversiy in Fisheries Management. In: Handbook of Marine Fisheries Conservation and Management. New York: Oxford University Press; 2010.

55. Diana JS. Aquaculture Production and Biodiversity Conservation. BioScience. 2009 Jan;59(1):27–38.

56. Crippa M, Solazzo E, Guizzardi D, Monforti-Ferrario F, Tubiello FN, Leip A. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat Food. 2021 Mar 8;2(3):198–209.

57. Pires APF, Srivastava DS, Marino NAC, MacDonald AAM, Figueiredo-Barros MP, Farjalla VF. Interactive effects of climate change and biodiversity loss on ecosystem functioning. Ecology. 2018 May;99(5):1203–13.

58. Bharucha Z, Pretty J. The roles and values of wild foods in agricultural systems. Phil Trans R Soc B. 2010 Sep 27;365(1554):2913–26.

59. Powell B, Thilsted SH, Ickowitz A, Termote C, Sunderland T, Herforth A. Improving diets with wild and cultivated biodiversity from across the landscape. Food Sec. 2015 Jun;7(3):535–54.

60. Jones AD. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. Nutrition Reviews. 2017 Oct 1;75(10):769–82.

61. Swindale A, Bilinsky P. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2) [Internet]. Washington, D.C.: FHI 360/FANTA; 2006. Available from: https://www.fantaproject.org/sites/default/files/resources/HDDS_v2_Sep06_0.pdf

62. Moursi MM, Arimond M, Dewey KG, Trèche S, Ruel MT, Delpeuch F. Dietary Diversity Is a Good Predictor of the Micronutrient Density of the Diet of 6- to 23-Month-Old Children in Madagascar3. The Journal of Nutrition. 2008 Dec;138(12):2448–53.

63. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels MC, Deitchler M, et al. Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women's Diets in 5 Diverse, Resource-Poor Settings. The Journal of Nutrition. 2010 Nov;140(11):2059S-2069S.

64. Lachat C, Raneri JE, Smith KW, Kolsteren P, Van Damme P, Verzelen K, et al. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. Proc Natl Acad Sci USA. 2018 Jan 2;115(1):127–32.

65. Halwart M. Biodiversity and nutrition in rice-based aquatic ecosystems. Journal of Food Composition and Analysis. 2006 Sep;19(6–7):747–51.

66. Phong LT, Udo HMJ, Van Mensvoort MEF, Bosma RH, Tri LQ, Nhan DK, et al. Integrated Agriculture-Aquaculture Systems in the Mekong Delta, Vietnam: An Analysis of Recent Trends. 2007 [cited 2023 Jul 10]; Available from: https://ageconsearch.umn.edu/record/166012

67. Hasimuna OJ, Maulu S, Nawanzi K, Lundu B, Mphande J, Phiri CJ, et al. Integrated agriculture-aquaculture as an alternative to improving small-scale fish production in Zambia. Front Sustain Food Syst. 2023 May 10;7:1161121.

68. Drewnowski A. Defining nutrient density: development and validation of the nutrient rich foods index. J Am Coll Nutr. 2009;28(4):421S-426S.

69. Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proc Natl Acad Sci USA. 2014 Mar 18;111(11):4001–6.

70. Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature. 2000 Feb;403(6772):853–8.

71. Leclère D, Obersteiner M, Barrett M, Butchart SHM, Chaudhary A, De Palma A, et al. Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature. 2020 Sep 24;585(7826):551–6.

72. Cobbinah PB, Black R, Thwaites R. Biodiversity conservation and livelihoods in rural Ghana: Impacts and coping strategies. Environmental Development. 2015 Jul;15:79–93.

73. Nganso TB, Kyerematen R, Obeng-Ofori D. Review of biodiversity in sacred groves in Ghana and implications on conservation. Current Trends in Ecology [Internet]. 2012;3. Available from: https://www.semanticscholar.org/paper/Review-of-biodiversity-in-sacred-groves-in-Ghana-on-Nganso-Kyerematen/2f6c6cbb69ca21bd3cbdef2593b68b008f8092b4

74. Ntiamoa-Baidu Y. Indigenous Beliefs and Biodiversity Conservation: The Effectiveness of Sacred Groves, Taboos and Totems in Ghana for Habitat and Species Conservation. jsrnc. 2008 Jan 16;2(3):309–26.

75. Sarfo-Mensah P, Oduro W. Traditional Natural Resources Management Practices and Biodiversity Conservation in Ghana: A Review of Local Concepts and Issues on Change and Sustainability. SSRN Journal [Internet]. 2007 [cited 2023 Jul 10]; Available from: http://www.ssrn.com/abstract=1017238

76. Vernooy R. The potential of agrobiodiversity for improving diets and nutrition in Ghana [Internet]. The Alliance of Bioversity International and CIAT; 2021. Available from: https://cgspace.cgiar.org/bitstream/handle/10568/116295/The%20potential_Vernooy_2021.pdf

77. Joseph B, Matilda Ntowa B, Edmund Osei O, Rashied T, Richard AA, Yaw K, et al. Sustainable Food System in Ghana: Role of Neglected and Underutilized Crop Species and Diversity. Anthr Sci. 2023 Mar 29;2(1):62–70.

78. Zonneveld M, Kindt R, Solberg SØ, N'Danikou S, Dawson IK. Diversity and conservation of traditional African vegetables: Priorities for action. Lambrinos J, editor. Divers Distrib. 2021 Feb;27(2):216–32.

79. Benhin JKA, Barbier EB. Structural Adjustment Programme, Deforestation and Biodiversity Loss in Ghana. Environmental and Resource Economics. 2004 Mar;27(3):337–66.

80. Onumah EE, Quaye EA, Ahwireng AK, Campion BB. Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. Sustainability. 2020;12(19):7932.

81. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana's evolving protein economy. Food Security. 2016;8(5):909–20.

82. deGraft-Johnson KAA, Blay J, Nunoo FKE, Amankwah CC. Biodiversity Threats Assessment of the Western Region of Ghana". The Integrated Coastal and Fisheries Governance (ICFG) Initiative Ghana [Internet]. Narragansett, RI, USA: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2010. Available from: https://pdf.usaid.gov/pdf_docs/pnaeb985.pdf

83. Armah AK, Wiafe G, Kpelle DG. Sea-level rise and coastal biodiversity in West Africa: a case study from Ghana. In: Climate Change and Africa. Cambridge, UK: Cambridge University Press; 2005. p. 204–17.

84. Lazar N, Yankson K, Blay J, Ofori-Danson P, Markwei P, Agbogah K, et al. Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018. Report No.: GH2014_SCI042_CRC.

85. Atta-Mills J, Alder J, Rashid Sumaila U. The decline of a regional fishing nation: The case of Ghana and West Africa. Natural Resources Forum. 2004 Feb;28(1):13–21.

86. Alder J, Campbell B, Karpouzi V, Kaschner K, Pauly D. Forage Fish: From Ecosystems to Markets. Annu Rev Environ Resour. 2008 Nov 1;33(1):153–66.

87. Apetorgbor S. Closed Season Brief. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018 p. 10. Report No.: GH2014_POL109_CRC.

88. Owusu V, Adu-Boahen K, Kyeremeh S, Demalie I, Eshun P. Factors influencing compliance of closed fishing season: lessons from small-scale coastal fisheries in the Central Region of Ghana. Humanit Soc Sci Commun. 2023 Jan 17;10(1):20.

89. Ministry of Food and Agriculture, Fisheries Commission. Ghana National Aquaculture Development Plan (GNADP) [Internet]. Accra, Ghana: Ministry of Food and Agriculture; 2012. Available from: https://faolex.fao.org/docs/pdf/gha149443.pdf

90. Ragasa C, Andam KS, Asante SB, Amewu S. Can local products compete against imports in West Africa? Supply- and demand-side perspectives on chicken, rice, and tilapia in Ghana. Global Food Security. 2020;26.

91. Ragasa C, Agyakwah SK, Asmah R, Mensah ETD, Amewu S, Oyih M. Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana. Aquaculture. 2022 Jan;547:737476.

92. Read QD, Hondula KL, Muth MK. Biodiversity effects of food system sustainability actions from farm to fork. Proc Natl Acad Sci USA. 2022 Apr 12;119(15):e2113884119.

93. FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome: FAO; 2022.

94. Shahidi F, Ambigaipalan P. Omega-3 Polyunsaturated Fatty Acids and Their Health Benefits. Annual Review of Food Science and Technology. 2018;9:345–81.

95. Bogard JR, Thilsted SH, Marks GC, Wahab MA, Hossain MAR, Jakobsen J, et al. Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. Journal of Food Composition and Analysis. 2015;42:120–33.

96. Hicks CC, Cohen PJ, Graham NAJ, Nash KL, Allison EH, D'Lima C, et al. Harnessing global fisheries to tackle micronutrient deficiencies. Nature. 2019;574(7776):95–8.

97. Kawarazuka N, Béné C. The potential role of small fish species in improving micronutrient deficiencies in developing countries: Building evidence. Public Health Nutrition. 2011;14(11):1927–38.

98. De Guzman A, Sumalde ZM, Rance GMS, Colance MDB, Ponce MFV. Contribution of Gleaning Fisheries to Food Security and Nutrition of Poor Coastal Communities in the Philippines. Journal of Environmental Science and Management [Internet]. 2019;S1-1. Available from: https://ovcre.uplb.edu.ph/journals-uplb/index.php/JESAM/article/view/346/322

99. Gibson E, Stacey N, Sunderland TCH, Adhuri DS. Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, eastern Indonesia. PLoS One. 2020;15(4):e0230777.

100. Hasselberg AE, Aakre I, Scholtens J, Overå R, Kolding J, Bank MS, et al. Fish for food and nutrition security in Ghana: Challenges and opportunities. Global Food Security. 2020;26:100380.

101. Aura CM, Owiti H, Nyamweya C, Odoli CO, Obuya JA, Ogari Z, et al. Aligning small indigenous fish species (SIS) in policy and management for enhanced food security and nutrition: The case of the Kenyan Lake Victoria Omena fishery. Lakes & Reservoirs [Internet]. 2022 Mar [cited 2023 Jul 10];27(1). Available from: https://onlinelibrary.wiley.com/doi/10.1111/lre.12399

102. Wessels L, Kjellevold M, Kolding J, Odoli C, Aakre I, Reich F, et al. Putting small fish on the table: the underutilized potential of small indigenous fish to improve food and nutrition security in East Africa. Food Sec [Internet]. 2023 May 18 [cited 2023 Jul 10]; Available from: https://link.springer.com/10.1007/s12571-023-01362-8

103. Bogard JR, Farook S, Marks GC, Waid J, Belton B, Ali M, et al. Higher fish but lower micronutrient intakes: Temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh. PLoS One. 2017;12(4):e0175098.

104. Castine SA, Bogard JR, Barman BK, Karim M, Mokarrom Hossain Md, Kunda M, et al. Homestead pond polyculture can improve access to nutritious small fish. Food Sec. 2017 Aug;9(4):785–801.

105. Hossain MA, Afsana K, Azad Shah AKM. Nutritional value of some small indigenous fish species (SIS) of Bangladesh. Bangladesh Journal of Fisheries Research. 1999;3(1):77–85.

106. Islam MR, Yeasmin M, Sadia S, Ali MS, Haque AR, Roy VC. Small Indigenous Fish: A Potential Source of Valuable Nutrients in the Context of Bangladesh. Hydrobiology. 2023 Feb 6;2(1):212–34.

107. La Frano MR, Cai Y, Burri BJ, Thilsted SH. Discovery and biological relevance of 3,4-didehydroretinol (vitamin A_2) in small indigenous fish species and its potential as a dietary source for addressing vitamin A deficiency. International Journal of Food Sciences and Nutrition. 2018 Apr 3;69(3):253–61.

108. Reksten AM, Somasundaram T, Kjellevold M, Nordhagen A, Bøkevoll A, Pincus LM, et al. Nutrient composition of 19 fish species from Sri Lanka and potential contribution to food and nutrition security. Journal of Food Composition and Analysis. 2020 Aug;91:103508.

109. Roos N, Islam MM, Thilsted SH. Small Indigenous Fish Species in Bangladesh: Contribution to Vitamin A, Calcium and Iron Intakes. The Journal of Nutrition. 2003 Nov;133(11):4021S-4026S.

110. Roos N, Wahab MA, Chamnan C, Thilsted SH. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. J Nutr. 2007;137(4):1106–9.

111. Roos N, Leth T, Jakobsen J, Thilsted SH. High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency. International Journal of Food Sciences and Nutrition. 2002 Jan;53(5):425–37.

112. Sarma M, Pais J. Financial Inclusion and Development: A Cross Country Analysis. In Annual Conference of the Human Development and Capability Association, New Delhi. 2008;168(10–13):1–30.

113. Herforth A, Arimond M, Álvarez-Sánchez C, Coates J, Christianson K, Muehlhoff E. A Global Review of Food-Based Dietary Guidelines. Advances in Nutrition. 2019;10(4).

114. Kennedy ET, Ohls J, Carlson S, Fleming K. The Healthy Eating Index. Journal of the American Dietetic Association. 1995;95(10):1103–8.

115. Krebs-Smith SM, Pannucci TE, Subar AF, Kirkpatrick SI, Lerman JL, Tooze JA, et al. Update of the Healthy Eating Index: HEI-2015. J Acad Nutr Diet. 2018;118(9):1591–602.

116. Shams-White MM, Pannucci TE, Lerman JL, Herrick KA, Zimmer M, Meyers Mathieu K, et al. Healthy Eating Index-2020: Review and Update Process to Reflect the Dietary Guidelines for Americans, 2020-2025. Journal of the Academy of Nutrition and Dietetics. 2023 May;S2212267223002460.

117. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean diet and survival in a Greek population. N Engl J Med. 2003;348(26):2599–608.

118. Martínez-González MA, Salas-Salvadó J, Estruch R, Corella D, Fitó M, Ros E. Benefits of the Mediterranean Diet: Insights From the PREDIMED Study. Progress in Cardiovascular Diseases. 2015 Jul;58(1):50–60.

119. Mitra S, Khatun MostN, Prodhan MdMH, Khan MdA. Consumer preference, willingness to pay, and market price of capture and culture fish: Do their attributes matter? Aquaculture. 2021 Nov;544:737139.

120. Uddin MdT, Rasel MH, Dhar AR, Badiuzzaman Mr, Hoque MdS. Factors Determining Consumer Preferences for Pangas and Tilapia Fish in Bangladesh: Consumers' Perception and Consumption Habit Perspective. Journal of Aquatic Food Product Technology. 2019 Apr 21;28(4):438–49.

121. Thilsted SH, James D, Toppe J, Subasinghe R, Karunasagar I. Maximizing the contribution of fish to human nutrition. In FAO and World Health Organization; 2014. Available from: http://www.fao.org/3/a-i3963e.pdf

122. Ministry of Food and Agriculture and University of Ghana School of Public Health. Food-Based Dietary Guidelines [Internet]. 2023. Available from: https://mofa.gov.gh/site/images/pdf/Ghana_Food_Based_Dietary_Guidelines_2023.pdf

123. Vincent A, Grande F, Compaoré E, Amponsah Annor G, Addy PA, Aburime LC, et al. FAO/INFOODS Food Composition Table for Western Africa (2019) User Guide & Condensed Food Composition Table / Table de composition des aliments FAO/INFOODS pour l'Afrique de l'Ouest (2019) Guide d'utilisation & table de composition des aliments condensée. Rome: Food and Agriculture Organization of the United Nations; 2020.

124. Armar-Klemesu M, Osei-Menya S, Zakariah-Akoto S, Tumilowicz A, Lee J, Hotz C. Using Ethnography to Identify Barriers and Facilitators to Optimal Infant and Young Child Feeding in Rural Ghana: Implications for Programs. Food Nutr Bull. 2018;39(2):231–45.

125. Colecraft E, Marquis GS, Aryeetey R, Sakyi-Dawson O, Lartey A, Ahunu B, et al. Constraints on the Use of Animal Source Foods for Young Children in Ghana: A Participatory Rapid Appraisal Approach. Ecology of Food and Nutrition. 2006 Oct;45(5):351–77.

126. Bandoh DA, Kenu E. Dietary diversity and nutritional adequacy of under-fives in a fishing community in the central region of Ghana. BMC Nutr. 2017 Dec;3(1):2.

127. Mingle CL, Darko G, Asare-Donkor NK, Borquaye LS, Woode E. Patterns in protein consumption in Ghanaian cities. Scientific African. 2021 Mar;11:e00684.

128. Akuffo A S, Quagrainie KK, Obirikorang KA. Analysis of the determinants of fish consumption by households in Ghana. Aquaculture Economics & Management. 2020;24(3).

1.6 Tables and figures

Table 1.1: Nutrient composition of highly consumed fish and seafood in Ghana, per 100 grams of edible portions (123).

Species/genera	Total protein (g)	Total PUFA (g)	Calcium (mg)	Iron (mg)	Zinc (mg)	Vitamin A (RAE)[1]
Anchovy, canned in oil	28.9	2.68	232	4.6	2.44	12
Anchovy, fillet, raw	18.9	1.88	89	1.6	1.47	14
Barracuda, fillet, raw	19.0	0.19	21	0.8	0.42	25
Crab, flesh, raw	16.0	0.48	63	1.6	4.27	232
Mackerel, fillet, raw	19.6	1.22	34	1.6	0.74	82
Mackerel, canned in oil	23.2	0.17	241	2.0	1.02	130
North African catfish, fillet, raw	17.8	1.16	23	0.5	1.07	9
Sardine, canned in oil	24.8	6.12	421	2.4	1.77	49
Sardine, fillet, raw	19.8	0.61	50	1.7	1.53	13
Shrimp, flesh, raw	21.6	0.26	66	1.6	1.30	56
Tilapia, fillet, raw	18.6	0.30	109	1.7	0.91	10
Tuna, canned in oil	25.4	0.30	7	0.9	0.72	17
Tuna, fillet, raw	23.6	0.91	11	1.0	0.39	14

[1]Retinol activity equivalents

Chapter 2 A Qualitative Study of Food Systems Linkages With Fish and Seafood Consumption in Accra, Ghana

2.1 Introduction

Food systems in low- and middle-income countries (LMICs) are rapidly changing due to agricultural development and sociodemographic shifts (1–3). One consequence of food systems change is the nutrition transition, which sees populations move from low variety diets composed of starchy staples, fruits, and vegetables to higher variety diets reliant on processed foods rich in sugar and fat as their incomes increase (4).

Similar to other LMICs, Ghana is undergoing a nutrition transition amidst significant food systems change (5–7). Undernutrition persists, affecting more than one quarter of children aged under five years (7). Concurrently, the prevalence of adult obesity has increased to 17.1% of the adult population, with significant disparities between women and men (21.9% versus 6.0%) and urban and rural settings (20.6% versus 8.0%) (8). This emergence of obesity as a pressing public health issue is concomitant with increased consumption of ultra-processed foods (8). National and international companies have recently established supermarkets in large urban centers, but traditional open air markets remain a mainstay of food consumer behavior, particularly for the non-wealthy (6,9).

In Ghana, fish and seafood is a culturally and economically important food that contributes vital nutrition across socioeconomic levels (10,11). Fish and seafood represents more than 60% of total household expenditure on animal protein-rich foods (12). Many types of fish and seafood are purchased and sold in local open markets (13), including smaller indigenous fish species that contain important nutrients like vitamin A, iodine, iron, zinc, protein, and polyunsaturated fatty acids or fish oils (14). Ghana's food-based dietary guidelines promote fish and seafood consumption, especially oily marine fish to reduce cardiovascular disease risk (15).

More than two million people rely on Ghana's fisheries for their livelihoods (16), of whom nearly 20% are women (17) who work across the food system as fish smokers or market vendors, among other roles (13,18,19). Together, Ghana's fisheries and aquaculture produces approximately 440,000 tons of fish and seafood each year, which generate over USD $1 billion or 4.5% of national gross domestic product (GDP) (16).

Many changes to Ghana's food and nutrition landscape are driven by its fisheries and aquaculture sector. Key marine fisheries for sardinella, anchovies, and mackerel have trended toward decline and collapse, which has spurred fisheries closures that aim to protect and replenish these valuable stocks (20). Though national fish and seafood consumption has remained stable over this period, poorer households have increased their consumption while wealthier households have slightly decreased theirs (12). Increased reliance on imports and government efforts to scale up freshwater aquaculture production in Lake Volta could mitigate the gap between marine fisheries production and consumer demand (21–26). However, emerging evidence suggests that higher reliance on aquaculture could limit micronutrient intake as farmed fish species are less nutrient dense than those that are wild caught (27).

In combination, these food system factors and their associated changes create variable consumer behaviors for fish and seafood. For example, consumers living in low socioeconomic settings might consume cheaper types of fish and seafood with the intent to fulfill nutrition requirements in contrast with higher-income consumers preferring expensive types that appeal to their tastes and preferences (28). Understanding these factors and their influence on consumer behaviors can provide valuable information for designing policies and interventions that target a multitude of food system goals, including fisheries sustainability, food security, and solving Ghana's triple burden of malnutrition, or undernourishment, overnutrition, and micronutrient deficiencies occurring at the same time (29).

To this end, the purpose of this study was to understand how fish and seafood consumption is influenced by food system components in various socioeconomic settings in Accra, Ghana. We used qualitative research methods to collect detailed information about fish and seafood consumer behaviors, especially related to consumer perceptions of fisheries and aquaculture, food processing, market accessibility, food safety, culture and religion, tastes and preferences, and sustainability. We primarily interviewed fish and seafood consumers located in low-, middle-, and high-income neighborhoods in Accra, Ghana. We also interviewed several people in key food systems roles, including members of the canoe fishermen's union, fish and seafood smokers, and market vendors, to triangulate fish and seafood consumer perspectives. Our overarching research question was: How do various aspects of the food system influence consumer behavior toward fish and seafood across socioeconomic contexts? In addressing this research question, we aimed to 1.) describe different consumer behavior toward fish and seafood; b.) identify food system factors and their relationships that influenced or explained those consumer behaviors; and c.) assess similarities or differences across socioeconomic contexts.

2.2 Methods

2.2.1 Philosophy of science and methods

There is a complex network of food systems-related factors that work independently or in concert to influence individual consumer behavior toward fish and seafood. Food systems, whose components encompass food production, processing, distribution, consumption, and waste, is a framework for identifying these factors and their interrelationships (30). Qualitative research methods are well-suited to identifying and describing these relationships as their flexibility allows researchers to accommodate new information and embrace individual experiences and perspectives. We conducted this study in line with Postpositivist and Social Constructionist ontologies and epistemologies (31). We based our study on the assumption that fish and seafood are highly consumed across Accra, Ghana, though we sought to understand the thoughts and opinions of individuals on their fish and seafood consumption as informed by their unique background and experiences. Furthermore, we used semi-structured interview guides that were tailored to each person's food system role, i.e., we asked questions about fishery policies to fishery managers that we did not pose to market vendors. These interview guides allowed us to collect information on people's perceptions of fish and seafood for physical health and nutrition, how their social or economic identities influence their fish and seafood consumption behaviors, and their ideas for how the broader food system and its components influence them. We analyzed the contents of these interviews using thematic analysis by iteratively coding the data, identifying themes and patterns, and summarizing those themes and patterns in the context of Accra's food system.

Participants and sampling procedures

This study focused primarily on fish and seafood consumers living in Accra, Ghana. We selected Accra as the study setting because it hosts key food system components that exist in manifold ways with reasonable access to consumers. For example, fish and seafood distribution are all present as seaside landing sites, open markets, supermarkets, and restaurants in proximity. A second reason is that Accra's population is socioeconomically diverse, featuring residents of various income levels, occupations, ethnicities, and religions.

We used a purposeful stratified sampling strategy in order to reach a group of socioeconomically diverse fish and seafood consumers. To do this, we set out to and completed interviews with 10 fish and seafood consumers from low-income neighborhoods, 9 from middle-income neighborhoods, and 10 from high-income neighborhoods; this sample size is consistent with previous research on meeting data saturation (32). We used neighborhood environments as a proxy for socioeconomic status and selected six neighborhoods in the Accra Metropolitan Area based on their average household income level, diversity of housing environments, and diversity of food system components. East Legon is a high-income neighborhood that has at least two large supermarkets and no open markets. East Legon also hosts the University of Ghana, which was our study headquarters during field data collection. Osu is a high-income neighborhood with a high level of income and food system diversity as evidenced by prominent slum formations, supermarkets, restaurants and hotels, and a large open market. Kaneshie is a middle-income neighborhood that is home to Accra’s largest open market; Odorkor is another middle-income neighborhood without a prominent open market but does contain slum formations. James Town and Chorkor are both low-income neighborhoods that feature many types of fisheries activities, including seaside landing sites for canoe fishermen, space for fish smoking operations, and open markets. Many residents of the Ga ethnicity live in these neighborhoods, and James Town hosts the annual Ga Homowo festival, an event that involves fishing and fish and seafood (33).

To recruit fish and seafood consumers for interviews, the study team began in the geographic center of each neighborhood or a nearby street intersection. From there, the study team split up and each member walked in a single direction. We knocked on doors and asked if people would be willing to be interviewed and initiated the informed consent procedure if they were amenable. We exclusively interviewed women based on previous qualitative research conducted in Accra supporting the significant role that women have in food purchasing and family feeding (34). Other criteria specified that interviewees consume fish and seafood, as well as live in households with children. The second criterion was in place to ensure the collection of information on fish and seafood consumption among infant, child, and adolescent life stages. We did not include people who were under the age of 18 years or were pregnant at the time of interview due to their status as vulnerable populations in research under United States federal regulations.

We also interviewed 7 individuals who work in food system roles that are important to fish and seafood consumption. Our goal was to interview at least one person who represents fisheries production, fish and seafood processing, and fish and seafood distribution in order to corroborate or add context to the information collected from fish and seafood consumers. We intentionally sought and coordinated a joint interview with members of the canoe fishermen's union in James Town. Our interviews with the two fish smokers from James Town and Chorkor, two market vendors in Odorkor and Kaneshie, and a chef in Kaneshie occurred by visiting their employment sites and asking if they had time to be interviewed about their work.

2.2.2 Ethical considerations

Prior to each interview, we verbally presented the research study by describing the study purpose, benefits and risks to participating, confidentiality of records, compensation for participation, how to withdraw, and who should be contacted for further information. We gave each prospective interviewee a typed copy of that information to keep and dedicated time to read it over independently and ask questions. The study was reviewed and determined exempt by the Institutional Review Board (IRB) of the University of Michigan (HUM00162776) and approved by the University of Ghana Ethics Committee for Basic and Applied Sciences (ECBAS).

2.2.3 Interview procedures

The semi-structured interview guides were created by ZPG, the lead author of this manuscript, and reviewed by DBS, who advised on the study implementation. The guides were then submitted to the University of Michigan IRB and the University of Ghana ECBAS and approved. We conducted all the interviews in-person and in the local languages, Twi or Ga. Interviews ranged in duration from 30 minutes to one hour and their audio was recorded with permission. After each day of interviews, the data collection team met to discuss any notes of interest. Interviews were translated and transcribed to English by research assistants who were natively fluent in Ga or Twi. We have provided sample questions from interview guides in Table 2.1.

2.2.4 Data analysis

We analyzed the interview data according to the guide to thematic analysis proposed and described by Clarke & Braun (2006) (35). During data collection, ZPG facilitated a daily review of the interview contents with the research team to identify noteworthy findings. After data collection had finished, ZPG reviewed the data corpus and generated an initial list of codes and definitions that pertained to the overarching research question and the study aims. Then, ZPG and MNAA, the lead research assistant, independently reviewed the data set and assigned codes to data items. Once finished, ZPG and MNAA reviewed the coded datasets together and addressed any incongruencies. ZPG reviewed the harmonized coded dataset to identify themes and patterns and refine them according to their relevance to the overarching research question. We considered themes in terms of their prevalence, or how often they appeared across the dataset, and importance to addressing the study's overarching research question. Since our overarching research question was established using a food system framework, our approach to thematic analysis was theoretical in nature, as opposed to inductive. ZPG presented the preliminary findings to ADJ, the study supervisor, and further refined the themes and patterns in discussion.

2.3 Results

We interviewed 29 fish and seafood consumers and 7 people in food system roles in six neighborhoods of Accra. Sociodemographic characteristics of the fish and seafood consumers sampled are presented in Table 2.2. All consumers identified as Christian and some specified denominations, such as Methodist or Apostolic, and as either Ga-Dangme or Akan ethnicity. Most had completed some high school education. The consumer sample skewed above 40 years of age.

Thematic analysis of the interview data elucidated important ways that food system components influence consumer behavior toward fish and seafood across socioeconomic contexts through four key themes (Figure 2.1). This first theme captures how components of the food system shape how fish and seafood appeal to individual tastes and preferences. The second theme discusses how the food system affects the real or perceived nutritional quality of fish and seafood and health outcomes associated with its consumption. The third theme covers the social, cultural, and religious factors that mediate linkages between the food system and fish and seafood consumption. Finally, the fourth theme describes the cost and convenience of fish and seafood to differentially influence consumer behavior.

2.3.1 Theme 1: Tastes and preferences

2.3.1.1 Types of fish and seafood consumed

The production, import, and distribution of various types of fish and seafood appealed differentially to interviewees in the sample. In total, interviewees reported consuming 22 distinct fish and seafood species/genera that are produced in both freshwater and marine environments. Examples of fish included mackerel, herring, anchovy, barracuda, tilapia, and catfish; molluscs included oyster and octopus; and crustaceans included crab, shrimp, and snail. While interviewees consumed a variety of fish and seafood regardless of neighborhood location and corresponding socioeconomic classes, some trends emerged. Four types of fish (mackerel, tuna, barracuda, and tilapia) were consumed by interviewees in every neighborhood. The context of their consumption could represent sentinel ways that fish and seafood consumer behavior is affected by food system components. Mackerel was frequently mentioned as a staple fish in traditional Ghanaian dishes and among the healthiest fish to eat among other foods. Tuna held dual roles as a food served during cultural celebrations and convenient for feeding entire families because of its large size. Barracuda was considered tasty, but interviewees said it was relatively expensive. Finally, tilapia was versatile food that could be found fresh, salted, or fried in markets or restaurants.

2.3.1.2 Preferences for fish and seafood

Sensory perceptions influenced interviewee preferences for fish and seafood species/genera. Tuna, redfish, barracuda, and tilapia were all frequently described by interviewees as tasty or delicious. Many liked mackerel and herring, but a couple interviewees strongly dissented. Regarding scent, one (3009_Kaneshie_Q4) said they hated the “stench” of mackerel and another (3011_Kaneshie_Q4) said they would “vomit immediately” if they ate it. Texture both positively and negatively affected preferences for mackerel and herring; for example, one interviewee (3005_JamesTownQ4) said that they liked the soft meat of mackerel compared to the harder flesh of herring. Many interviewees said they were afraid of eating octopus, with one (3001_EastLegon_Q3) disliking its many legs. A few interviewees from Osu disliked eel because it resembled snakes. Despite these preferences, other interviewees were content eating any fish or seafood, as one (1005_Chorkor_Q3) stated, "I eat any fish I am given."

Interviewees linked different processing or cooking methods with fish and seafood species or genera. Mackerel, herring, and catfish were often indicated as smoked by interviewees. Salted and dried products included cartilaginous fishes like shark or skate (called *kako*) and tilapia (called *koobi*), though tilapia could also be purchased as fresh or fried. Finally, a couple of interviewees mentioned *shito*, a condiment made from shrimp and other fish.

In general, interviewees described pairing fish and seafood with traditional dishes. Starchy staples like *banku*, *kenkey*, *fufu*, rice, or yams were served with mackerel, herring, anchovies, tuna, and tilapia. Fish and seafood were added to soups and stews while cooking for flavor and texture. While interviewees had personal preferences for which fish and seafood belonged to a specific dish, any combination of a mackerel, herring, tilapia, barracuda, redfish, or crab with groundnut soup, palm nut soup, light soup, kontomire stew, or okro stew sufficed. As one interviewee admitted, "I use mackerel, herring, and tuna for every dish… okro soup, palm nut soup, groundnut soup, light soup—everything" (3005_JamesTown_Q9).

Interviewees across neighborhoods said they preferred to eat fish and seafood in their homes. Some interviewees said they would visit restaurants or chop bars to eat tuna or tilapia, but they were strongly concerned with food safety. Interviewees preferred to buy fish and seafood at seashore landing sites or open markets but avoided cold stores and supermarkets because of their higher prices and distaste for frozen products.

2.3.1.3 Comparing preferences for fish and seafood to other animal source foods

Nearly all interviewees expressed that fish and seafood was the preferred alternative to other animal flesh foods or plant protein sources. The most common reason was that fish and seafood was the healthier option followed by finding fish and seafood tastier than meat. A couple of interviewees conveyed the perception that households who eat meat are indulgent. When asked what differentiates other households who eat meat, one said, “I think they love to enjoy themselves” (1002_Osu_Q8).

2.3.2 Theme 2: Health and Nutrition

2.3.2.1 Fish and seafood imparts health and nutrition

Across all neighborhoods, interviewees voiced their strongly held opinions about fish and seafood consumption and ways that it can improve or maintain health. Many said that fish and seafood imparts strength or promotes growth; others felt that fish and seafood kept them healthy. One interviewee said, “I haven’t gone to the hospital in a decade because I consume fish” (2002_EastLegon_Q10). Eating fish and seafood was also linked to a range of specific health conditions, including surgery recovery (1006_Chorkor_Q2), preventing gout (3004_Osu_Q1) and heart disease (1002_Osu_Q10), relieving high blood pressure and diabetes (1007_Odorkor_Q10). Two interviewees couched these health benefits in moderation by saying that consuming too much fish and seafood is bad.

Interviewees also noted that fish and seafood could impact health and nutrition across different life stages. During infancy, fish and seafood is used as a complementary food (“I give powdered mackerel or herring to complement breastfeeding”) or to improve the nutritional quality of other complementary foods (I can add powdered fish to palm nut soup to wean infants”) (3003_Osu_Q7, 3011_Kaneshie_Q7). For childhood, there was strong consensus that the nutrient-rich nature of fish and seafood spurs physical and cognitive growth. However, interviewees presented mixed ideas about fish and seafood for adulthood and the geriatric life stage. While one said, “I eat fish because I am old and need to eat with caution” (1002_Osu_Q1), others felt eating fish and seafood was unnecessary or harmful.

2.3.2.2 Augmenting the nutrition quality of fish and seafood

Interviewees generally perceived fish and seafood as beneficial to health and nutrition, though nutritional quality differed by species/genera or food processing and cooking methods. Oily marine fish and shellfish were all considered highly nutritious. Specifically, mackerel was a good source of fish oils and consuming sardinella was associated with “giving blood,” a characteristic connoted with strength and good health. Herring, crab, and oyster were all believed to have high calcium content, which could link to interviewee remarks about fish bones and crab shells as rich in calcium. In general, fish and seafood featured high protein content. However, tilapia was thought to be low in nutrient content and possibly detrimental to nutrition.

Despite linking high fish oil content to health benefits, several interviewees said that the process of smoking mackerel improves its nutritional quality by removing fish oils and preserving other nutrients. Frying fish and seafood, specifically tilapia, detracted from its nutritional quality by adding oil, though one interviewee considered the oil type: “I use palm kernel oil because I think it is healthier. Recently, Frytol introduced low cholesterol oil, so I want to see how that it works” (1002_Osu_Q2). When cooking, interviewees added fish and seafood to soups and stews to increase the meal’s overall nutritional quality; overcooking or reheating soups and stews diminished quality by depleting nutrients.

Regardless of species/genera or food processing or cooking method, interviewees believed fish and seafood to be more nutritious than poultry, red meat, or eggs but on the same plane as legumes and vegetables. One line of thought was that fish and seafood is inherently nutritious due to factors like higher protein content; another was that meat and poultry were less nutritious than fish and seafood because of higher fat content.

2.3.2.3 Healthcare providers recommend fish and seafood

Interviewees discussed how their healthcare providers shaped consumer behaviors. Doctors were said to recommend fish and seafood generally for preventing illness and giving strength or species/genera for certain health conditions. One interviewee recalled their sister's experience: "My sister's doctor advised her to eat snails after surgery to help her heal. Snails are good for bones, and the water in snails gives strength" (3008_Kaneshie_Q10). Another interviewee said their doctor recommended eating crab when they were pregnant, but they admitted they disregarded this order. Herring was suggested to help health conditions like malaria, falling ill, or having type A blood. Finally, one interviewee said they were wary of tilapia because their friends' doctors said to abstain from eating that type of fish.

2.3.2.4 Fish and seafood safety across the food system

Food safety was a persistent concern. Some interviewees shied away from tilapia because they felt negatively toward chemical use in aquaculture: "I eat less tilapia… because I heard they use chemicals when farming them" (2011_Odorkor_Q4). Interviewees also decried illegal fishing practices that "use chemicals," which members of the canoe fishermen's union explained could be dichlorodiphenyltrichloroethane (DDT). In their interview, the canoe fishermen said they knew that consumers were aware that DDT fishing could corrupt fish and seafood for human consumption and that exposure could cause health problems. DDT use in fishing is illegal in Ghana, as it bioaccumulates in the food web, impairs reproductive development in fishes, and is carcinogenic and neurotoxic to humans (36). Waste disposal in fisheries was another problem, including open defecation at the seashore, hospital waste dumped in the ocean, and plastic waste killing fish.

Food safety also influenced where interviewees purchased fish and seafood. Fish and seafood from seashore landing sites was considered fresher and more trustworthy than from open markets, cold stores, or restaurants and chop bars. Interviewees distrusted the food preparation at restaurants and chop bars and wondered if they would fall ill after eating. When visiting open markets, interviewees avoided vendors who do not cover their products to protect from flies or leave product out in the mud when raining. One interviewee described how they learned to identify spoiled product from fishermen featured on a local television talk show called Obonu TV: “Smoked mackerel should look soft; if the texture is hard, then it’s been smoked over and over again because it hasn’t sold. For tilapia, the gills must have fresh blood, not look dark in color” (3008_Kaneshie_Q12). Members of the canoe fishermen’s union and market vendors offered additional advice: fish caught using chemicals will look soft even after it is smoked and dried.

To keep fish and seafood safe after buying, one interviewee described their cooking preparation routine: “I use hot salty water to wash the tilapia before cooking. The hot water also helps remove the scales and keeps the fish firm” (3011_Kaneshie_Q6). Another said that smoking keeps fish and seafood from spoiling during storage by removing moisture content and fish oils (3006_JamesTown_Q10). Refrigeration access did not differ by neighborhood context; while some refrigerated their cooked fish and seafood, others re-smoked their fish and seafood, used well-ventilated baskets, or bought only what they need to eat.

2.3.3 Theme 3: Social, cultural, and religious factors

2.3.3.1 Social factors influence fish and seafood consumption

Social relationships and household roles all influenced the consumer behaviors toward fish and seafood. Interviewees used business relationships founded on trust to help them buy fish and seafood. When faced with rising prices, interviewees would rely on their vendor contacts to use credit or find a good deal. Others used their contacts when concerned with food safety: one interviewee said they trust that their vendor does not sell spoiled fish; another who is usually worried about hygiene in chop bars said they visit their sister's establishment.

Fish and seafood could also be gifted as favors. One interviewee explained, "People give me crab and oyster as gifts, maybe because I treat them well" (1002_Osu_Q5). Others received gifts from relatives who work across the food system, like free fish from children who are fishermen (2009_Odorkor_Q5) or from their daughter who works at a cold store (2007_Chorkor_Q5). Having a household member who works in the food system also appeared to affect the type of fish and seafood consumed. For example, one interviewee who sells smoked and dried fish said they eat their product (1007_Odorkor_Q5). Another said, "Our neighbor is a fishmonger; her household eats fresh fish, while we like our fish smoked" (2005_JamesTown_Q7).

Women and men had distinct roles in influencing fish and seafood consumption. For example, providing fish and seafood was conceived as a men's role in the household. One interviewee said, "The man of the house pays for the fish" (2005_JamesTown_Q7). Another interviewee whose husband is a fisherman said the fish and seafood he brings home is what they eat (2009_Odorkor_Q7). Women, on the other hand, exerted influence by cooking fish and seafood. Regardless of neighborhood or income class, many shared similar sentiments about their control, and said "they eat what I prepare" (1005_Chorkor_Q7), "What I cook is what they eat" (1007_Odorkor), and "I cook, so everyone eats the same kinds of fish" 3002_EastLegon_Q7). Their cooking decisions could also affect household purchasing decisions, as many also said that they actively promote fish and seafood consumption in their household.

2.3.3.2 Belonging to a culture in which fisheries and fish and seafood are important

Many interviewees discussed belonging to the Ga-Dangme ethnic group, which has deep historical ties to marine fishing (Akyeampong, 2007), as highly influential for consumer behavior. Those who identified as Ga differentiated their fish and seafood consumption. As one interviewee said, "Households like ours eat more fish; we eat any kind of fish. We are all Gas. We stay close to the seashore, we fish, and we know fish well. We think fish is the best food" (3008_Kaneshie_Q8). Another way that Ga culture influenced consumer behavior was through the Homowo Festival, which convenes Ga people annually to collectively deride hunger after abundant harvest (33). Many interviewees who identified as Ga mentioned eating two traditional dishes, *kpekple* (steamed fermented corn meal) and palm nut soup, with a range of smoked fish, including mackerel, herring, tuna, red snapper, redfish, or barracuda.

Other special occasions called for fish and seafood, including naming ceremonies, birthdays, funerals, and Christmas. Often, the types of fish and seafood offered were expensive and aimed toward serving guests. For example, one interviewee said, "I use redfish for birthdays because it looks nice and barracuda for funerals because you can divide it into many pieces" (3004_Osu_Q2).

2.3.3.3 Religion shapes perceptions of fish and seafood

Religion was another strong influence on consumer behavior. For example, many interviewees discussed fish and seafood as integral to Christianity. Some interviewees cited

Christian beliefs for rationalizing fish and seafood consumption: "God made fish for us to eat; that is why I eat fish" (2005_JamesTown_Q1) and "I eat everything God has sanctified, including fish" (2002_EastLegon_Q4). Fish smokers noted that Seventh Day Adventists do not consume fish and seafood that lack scales. One interviewee described a more expansive interpretation. Since God granted limitless fish and seafood consumption when bestowing man stewardship over the ocean, interventions like the government's fishing ban unreasonably challenged God's will (3008_Kaneshie_Q12).

2.3.4 Theme 4: Cost and Convenience

2.3.4.1 Fish and seafood availability

Most interviewees visited seaside landing sites or open markets, where the ready availability of fish and seafood vendors and products factored into consumer behavior. One interviewee said they preferred the seaside landing sites because the fish and seafood is plentiful and cheap (3007_Chorkor_Q5). Another who preferred the open markets liked how there were more vendors to visit (3011_Kaneshie_Q5).

Neighborhood context appeared to influence concerns about fish and seafood availability. Those living in the low-income neighborhoods of Chorkor and James Town were expressly not worried, which could be attributed to neighborhood seaside landing sites and cultural ties fishing through Ga ethnic group. Some residents of middle-income neighborhoods, Kaneshie and Odorkor, expressed concerns about availability and rising fish and seafood prices, but some noted that cheap options like sardinella are consistently available. Most interviewees in the high-income neighborhoods, Osu and East Legon, were not worried, despite relying on open markets farther down the fisheries value chain.

Ecological factors like time and space determined the availability of fish and seafood for consumers. Interviewees identified certain species/genera available during specific fishing seasons. Herring, tuna, and *tsile* (red fish) were abundant during July and August, barracuda during November and December, and mackerel and tilapia available year-round (tilapia is a farmed fish). Despite consistent availability, one fish smoker said that mackerel caught in March and April are lower in fish oil content, which consumers find undesirable, possibly due to its diminished nutritional quality or taste (1103_FishSmoker_Q3).

Interviewees who had recently moved to Accra noticed differences in the fish and seafood available in their hometowns. One refused to eat the crabs in Accra because its color is different than when fished in Ada Foah, a town 100 kilometers due east (3011_Kaneshie_Q3). Another explained their aversion to catfish was based on superstition: “I come from a village in Brong Ahafo where there is a river for the gods. We do not eat any catfish from this river, and I worry that catfish from other places might stem from this source” (1003_Osu_Q3). One fish smoker also said that imported mackerel have higher fish oil content than those caught domestically (1103_FishSmoker_Q3).

2.3.4.2 Value for time, effort, or money according to household needs

The value of fish and seafood for time, effort, or money strongly influenced consumer behavior, and interviewees discussed balancing these factors to decide where to buy fish and seafood.

The most frequently mentioned factor was the cost of fish and seafood at different distribution sources, but opinions of seaside landing sites, open markets, and cold stores varied. Two from James Town said that seaside landing sites and open markets were both “affordable” options (1005_JamesTown_Q5; 2005_JamesTown_Q5), but another said open markets are cheaper, despite having brothers who are fishermen and sell their catch at the seashore (3006_JamesTown_Q5). In Kaneshie, one interviewee preferred buying fish and seafood in open markets because cold stores are too expensive (3008_Kaneshie_Q5). A second interviewee from Kaneshie disagreed, “Cold stores are cheaper than open markets.” Regardless of neighborhood, interviewees unanimously characterized supermarkets as the most expensive: “Fish and seafood at the supermarket costs twice as much as the open market” (3011_Kaneshie_Q6).

Proximity was a less frequently mentioned motivating factor, as some interviewees chose seaside landing sites or open markets if nearby or on their commutes home. The availability of certain product types also factored into value. Some mentioned they could buy fish and seafood that was already processed; one interviewee said, “I buy fish that is already smoked because it saves me from doing it myself” (1006_Chorkor_Q5). Another from East Legon said they liked open markets because they could also trade and shop for home goods. (Q5). Finally, interviewees were motivated by meeting household needs efficiently. For example, some bought and smoked large tuna and used small portions to prepare their meals. Others chose mackerel and herring because their cheap cost meant they could feed their families: “For four cedis, I can buy herring, tomatoes, and onions to feed my children.” (3008_Kaneshie_Q2).

2.3.4.3 Fish and seafood as substitutes or complements

While prices for species/genera of fish and seafood varied, there was consensus on which were expensive types. Interviewees across neighborhood income classes said they could not afford tilapia, which they perceived as “for the rich” (2008_Kanesie_Q2). Higher prices for catfish were explained by its seasonal availability (1005_Chorkor_Q4). Interviewees thought *tsile* (redfish), barracuda, and *nkaen* (cassava fish) were tasty but expensive and relegated eating them to special occasions.

When asked how they would accommodate higher fish and seafood prices, interviewees across neighborhoods and income classes responded in three ways. The first way was to buy smaller portions of their preferred fish and seafood, as taste or nutritional quality might override the total amount purchased. One interviewee said, “It is better to buy an expensive, good fish than a cheap, bad fish” (3004_Osu_Q11), while another explained, “If you don’t have the money, you cut down and buy what you can afford.” (3007_Chorkor_Q11).

The second way was to buy other types of fish and seafood. One interviewee described their sequence of decisions: “If I try to buy mackerel but it is unavailable, I will buy tuna instead. If tuna is gone, then I will buy *amani* (herring)” (3004_Osu_Q11). Some interviewees stressed their rigid preferences for fish and seafood. When asked whether they worry about prices, one said, “Why should I? I will buy fish regardless of cost because I need it.” (3002_EastLegon_Q11)

The third and final way was to buy chicken, beef, eggs, or legumes. For two interviewees, buying beans was their last resort regardless of type of fish and seafood. One interview referenced seafood species/genera, “If mackerel is gone, then I will buy tuna. If tuna is gone, I will buy herring. If no other fish, then I will buy beans.” (3004_Osu_Q11). The other discussed distribution sources and food processing, “I usually buy smoked fish from the open market. If that is unavailable, I will buy frozen fish from the cold store and smoke it myself. If all those kinds are gone, then I will turn to beans. (3001_EastLegon_Q5). Besides tastes and preferences, interviewees who decided to eat animal source foods considered health and nutrition. One interviewee explained, “If all fish and seafood is gone, then I will buy chicken. We aren’t supposed to eat chicken, but it’s okay once in a while” (3008_Kaneshie_Q5). Another said they would buy beef if no other kinds of fish and seafood were available, but they believed that beef causes illness (3006_JamesTown_Q10).

2.3.4.4 Present concerns for the future

Regardless of neighborhood, income class, or proximity to fisheries, interviewees worried that fisheries production was unable to meet consumer demand, which some connected to increasing market prices or constrained incomes for fisheries workers. Two interviewees complained about the Ministry of Fisheries and Aquaculture Development's recent seasonal fishing ban. One felt the fishing ban did not produce results and lamented that fish and seafood was still scarce and expensive. Another disagreed with the ban for religious reasons: "The fishing ban is unreasonable. God created fish, and no man should challenge God" (3008_Kaneshie_Q12). Others found fault with the fishermen, who they accused of unsustainable practices like harvesting fingerlings and chemical fishing. One interviewee suggested Ghana's fisheries should pivot its focus to aquaculture and said, "without fish farming there wouldn't be enough to eat in Ghana" (3007_Chorkor_Q12). Others took a stronger stance and said these fishermen should be arrested (3004_Osu_Q12). Members of the canoe fishermen pinpointed the blame on illegal fishing and larger boats that trawl for their catch, explaining,

> "The trawlers catch all kinds of fishes, and after selecting what they want, they throw the rest back in the ocean. These discarded fishes, which we aren't supposed to catch anyway, definitely die. If they were brought to the seashore, people could eat them instead" (1102_FishManager_Q6).

The mismatch between fisheries production and fish and seafood demand was corroborated by canoe fishermen, fish smokers, and market vendors. Many felt that fish and seafood consumption had reached levels never seen before. As one fish smoker said, "It used to be that I would still have smoked mackerel left to sell at the end of the day. Now, it's all purchased by noon" (1103_FishSmoker_Q6). While consumers pointed to fish farming as a potential alternative, fish smokers said they rely heavily on imported fish and seafood. One said, "Without importing fish, this country wouldn't be able to satisfy consumers" (1101_FishSmoker_Q9).

Only one interviewee referenced global climate change, but painted a challenging future to navigate,

> "There are fewer fish these days. Polar ice is melting, sea levels are rising, and fish are swimming deeper into the ocean. Our fishermen can't catch them, and since they catch less here, they have to fish elsewhere. Sea level rise also impacts our fishing communities; heavy rains carry away our canoes and flood our houses close to the beach" (1002_Osu_Q12).

2.4 Discussion

Our study interpolates four themes that capture specific linkages between the food system of Accra, Ghana and consumption behaviors toward fish and seafood: tastes and preferences, health and nutrition, culture and religion, and cost and convenience. While these linkages are well-established across varying research literature, this study synthesizes the qualitative evidence underpinning these linkages to a food systems framework. Using the food systems framework, our results describe these consumer behaviors with regards to fish and seafood species/genera, fisheries production, fish and seafood distribution, and food processing and cooking methods and compare them across socioeconomic levels.

Tastes and preferences mediated the types of fish and seafood produced, distributed, and consumed across the food system. Interviewees reported consuming a wide range of fish and seafood species, corroborating previous research by Onumah et al. (2020), which found that urban Ghanaian households consumed 34 distinct fish species in one year (37). Accra is well-known as a hub for fisheries production, processing, and distribution, which could increase availability and accessibility of different species/genera of fish and seafood. The two low-income neighborhoods we visited for our research, James Town and Chorkor, are historical fishing communities where many marine species are brought to shore (38–41). They are also the sites where we interviewed both fish smokers, though other operations are located elsewhere in Accra (42). Several studies document the flow of fish and seafood products in and out of Accra. Mamprobi, a neighborhood directly north of Chorkor, is a regional supply center for smoked sardinella and anchovy (40). Smoked marine oily fishes are sent to northern Ghana from Accra (13,43); smoked catfish, on the other hand, travels to Accra from northern Ghana (43).

Interviewees across socioeconomic levels preferred consuming fish and seafood in traditional soups and stews served with traditional starchy foods, like *kenkey* or *banku*. This aligns with previous research that found traditional foods as important dietary components for urban, rural, and migrant Ghanaians (44). No interviewees in our sample reported accompanying fish and seafood with ultra-processed "western" foods, like instant noodles or pasta, despite being widely available and highly consumed in Accra (8,45). One reason for this disconnect could be that fish and seafood is exclusively attached to traditional culinary Ghanaian fare (46), even when prepared outside the home, like grilled tilapia (47). Another reason could be that instant noodles and pasta do not pair with fish and seafood because of cost or convenience factors. In a photovoice study of adolescent girls and women in Accra (48), a low-income participant was featured who said they eat instant noodles and sausage because they cannot afford fish. Of note, nutrition research that uses quantitative methods to assess the diet patterns of Ghanaian populations finds mixed correlations between fish and seafood, ultra-processed "western" foods, and traditional starchy staples, though sample populations vary by rurality, region, and life stage (44,49–54).

Perspectives on health and nutrition influenced how interviewees engaged with fish and seafood across the food system. Historically, Ghana's nutrition policies have focused on reducing infant and child malnutrition (8,55). In our sample, interviewees tied fish and seafood consumption to improving child growth and cognitive development. This matches previous research by Christian et al. (2015), which found near universal agreement among caregivers that animal source foods (ASFs) were important for child diets, and most said they would prioritize feeding ASFs to children over other household members (56). Healthcare providers emerged as an important driver of fish and seafood consumption, which corroborates qualitative research by Liguori et al. (2022) on a similar population of women living in Accra (48). However, the health and nutrition information reported by our sample, like consuming herring when sick with malaria, did not seem to align with medical or nutritional sciences. Other research conducted in rural Ghana describes healthcare providers providing nutrition counselling that recommended cereals, fruits and vegetables, and legumes and nuts, but not fish and seafood (57,58). At the national level, Parbey & Aryeetey (2022) reviewed past dissemination of food and nutrition information in Ghana, but did not find any campaigns or advertisements that covered fish and seafood in particular (59).

Interviewees perceived the nutritional quality of fish and seafood to differ by species/genera or food processing and cooking methods. Most perceptions mirror messaging featured in Ghana's recently released food-based dietary guidelines (15), such as recommending consuming oily marine fish and cooking methods like grilling, boiling, or steaming over smoking and frying. Consumer perceptions conspicuously diverge from the dietary guidelines regarding fish smoking, which many believed as healthy because they believed the process removes excess oils. The dietary guidelines recommend limiting smoked fish consumption. This aligns with abundant research linking traditional wood smoking methods in West Africa to carcinogenic polycyclic aromatic hydrocarbons (PAHs) (60). Oftentimes, these PAH levels far exceed safe limits as set by the European Commission (EC), which bars the importation of smoked fish from West Africa for this reason (61,62). Oily marine fish species may be of specific concern, as PAHs accumulate in fatty tissue (60). Two studies that sampled smoked fish and seafood products in Ghana found that PAH levels were higher in oily marine fish species than freshwater tilapia, and their levels far exceed the EC safe limits (63,64). The dietary guidelines warn about heavy metal exposure from consuming larger fish species, yet no interviewees expressed concerns regarding this topic. Their omission is particularly noteworthy, as there are several ways that heavy metals can pollute aquatic ecosystems and contaminate fish and seafood in Ghana. One local way that would impact our study sample is electronic waste at the Agbogbloshie disposal site in Accra, which often floods and pollutes adjacent water bodies like the Odaw River and the Korle Lagoon (65). These water bodies used to be important community fishing sites (66); recent research shows that inhabiting fish species contain unsafe levels of electronic waste metals like cobalt and lead (67). Another way is mercury use in artisanal gold mining in Ghana, which can contaminate proximate freshwater aquatic ecosystems. A panoply of research indicates some mercury contamination in samples of freshwater fish and seafood species near gold mining areas, but mercury levels and commensurate concern for human health consequences vary across studies (68–74). A final way is through bioaccumulation of mercury in marine ecosystems, but studies generally find low levels of mercury contamination in marine fish and seafood species in Ghana (73,75–79).

Food handling and safety drew abundant concerns. In a study of food vendors in Kumasi, Ghana, only 2.3% of the study population tested positive for typhoidal salmonella (80), though the present risk of enteric disease speaks to interviewees saying they only visit fish and seafood vendors they trust. Hasselberg et al. (2020) did not find Salmonella in fish and seafood products sold in Ghanaian markets but referenced other research in African settings that presents mixed evidence (81–84). Regardless, interviewees were wary of fish and seafood left out in markets too long, which could lead to spoiled products contaminated by pathogens (85) or houseflies (13).

Social, cultural, and religious factors connected consumer behaviors with various food system components. Ga ethnicity was one such important connection as expressed by the sample. Historically, Ga fishermen have shaped how fisheries operate in Ghana. Akyeampong (2007) described how migrant Ga fishermen brought Senegalese fishing techniques back to Ghana and how Ga traditions forbade marine fishing on Tuesdays to conserve fish stocks (10), a policy that still exists today (86). Ga men involved in fishing would supply women, especially their wives and relatives, fish for processing or consumption (87). This could explain why some interviewees, often those who identified as Ga ethnicity, received fish and seafood as gifts from family and friends.

Finally, interviewees' concerns for Ghana's fisheries performance impacted their perspectives on the cost and convenience of fish and seafood. Previous research finds associations between major (June to October) and minor (December through February) fishing seasons and household spending on fish and seafood (37,88). One determinant of household spending could be cost, as the fish and seafood prices change across fishing seasons (41), possibly due to market dynamics from restricted supplies of fresh fish (18,89). This study's qualitative findings support that consumers exhibit differential preferences for fish and seafood species/genera or food processing methods under varying price conditions. Previous quantitative research on Ghanaian consumer preferences fails to consider these differentiating factors by treating fish and seafood as a whole (88,90–93). Economics research on Asian consumer preferences for fish and seafood species are a possible blueprint for studying the Ghanaian context (94,95), as well as research in Ghana comparing preferences for terrestrial animal source foods, like poultry, red meat, or mutton (90).

Fishing seasons can proxy other food system concerns, such as fisheries decline. Overfishing has nearly collapsed Ghana's small pelagic fishery, which covers important species like sardinella, anchovy, and mackerel (20). To replenish these valuable fish stocks, the Ministry of Fisheries and Aquaculture Development (MoFAD) enacted its first fisheries closure in May 2019 (96). Our study corroborates other research that reports negative sentiments toward the closure, specifically that it would be ineffective in restoring the fishery (86) and constrain those who rely on it for income (89). Since this study's data collection in August 2019, the MoFAD has closed the fishery two more times in 2021 and 2022 (86). While reduced fishing could greatly improve fisheries production and fisherman livelihoods (20), the fish smokers and canoe fishermen we interviewed echoed the perspective that Ghana requires fish and seafood imports in order to meet consumer demand (23).

2.5 Strengths, Limitations, & Policy Implications

There are a couple limitations to this study. The small sample of 29 fish and seafood consumers and 7 people in food system roles limits generalizing the themes and patterns we extracted across the sample population. We also did not record when prospective interviewees refused to participate in our study, so we may have missed important information that is correlated with their decisions. Given these constraints, our drawing of the interviewee sample on the food system framework allowed us to cover fish and seafood production, processing, and distribution, in addition to our main priority of fish and seafood consumers. The food system framework also enriched our analysis because we could use interviewee perspectives to triangulate information and identify key throughlines. For example, we were able to note where fish and seafood species/genera (e.g., aquatic biodiversity) or food processing and cooking methods appear in the food system and how each impacts consumer behaviors. It was possible to include a range of food systems roles in our interviewee sample by situating our research in Accra, an important hub for fish and seafood.

The study setting of Accra could limit the transferability of our qualitative findings to rural or inland West African contexts. However, there is significant evidence that inland and rural areas in Ghana also have considerable access to fish and seafood that include different species/genera or food processing, freshwater production sources, and distribution flows (43,89,97). As for the urbanity of our research, Ghana's urban population is increasing, reaching 56.7% of the total population with much of the growth occurring in Accra (98). Other similar coastal metropolitan settings include Lagos, Nigeria, Abidjan, Côte d'Ivoire, Conakry, Guinea, and Dakar, Senegal.

Ghana's recently released food-based dietary guidelines embrace the multidimensional nature of fish and seafood consumption behaviors. Therefore, our findings could be applied to implementing these guidelines in ways that cut across food system components and socioeconomic levels. For one example, policymakers could develop nutrition education campaigns that reinforce fish and seafood safety across the food system, especially targeting misconceptions about smoked fish or lack of awareness of heavy metal contamination. Practitioners, such as nutrition counsellors, could tailor dietary advice that leverages existing consumer behaviors like choosing fish and seafood for health and nutrition. Finally, key qualitative findings contradict or provide new insight into previous research, prompting future studies that reexamine fish and seafood in diet patterns or relationships between food prices and fish and seafood consumption.

2.6 Conclusion

Fish and seafood remains important in Ghana amidst a changing food system. In this qualitative study, we interpolate four themes under which the food system of Accra exerts influence on fish and seafood consumer behaviors. The interviewee sample exhibited a wide range of tastes and preferences, consuming 22 fish and seafood species/genera in traditional soups and stews alongside starchy staples like *kenkey* or *banku*. In general, interviewees perceived fish and seafood as beneficial to health and nutrition. Several specific benefits were tied to fish and seafood species/genera or food processing and cooking methods, some of which were communicated by healthcare providers. Food safety across fisheries production, food processing, and markets and distribution highly influenced consumer behaviors. Social networks were important for procuring fish and seafood; religious and ethnic identities dictated preferences for specific types. Interviewees also described how financial and time costs factor into their consumer behaviors. Interviewees were mixed on which distribution sources were most convenient, but they largely agreed that fish and seafood was worth the premium over other protein-rich foods, like red meat, poultry, and pulses, legumes, or nuts. Finally, there was widespread concern for the sustainability of fish and seafood in Ghana regarding climate change, imports, and illegal fishing practices. Subsequent qualitative research could explore misconceptions on fish and seafood smoking and the role of healthcare providers in incentivizing fish and seafood consumption. Future quantitative research could explore how different types of fish and seafood fit into diet patterns or consumer preferences under varying price or income conditions.

2.7 References

1. Jayne TS, Muyanga M, Wineman A, Ghebru H, Stevens C, Stickler M, et al. Are medium-scale farms driving agricultural transformation in sub-Saharan Africa? Agricultural Economics. 2019 Nov;50(S1):75–95.

2. Popkin BM. Nutrition, agriculture and the global food system in low and middle income countries. Food Policy. 2014 Aug;47:91–6.

3. Reardon T. Growing food for growing cities: Transforming food systems in an urbanizing world. Chicago, USA: The Chicago Council on Global Affairs; 2016.

4. Popkin BM. Nutritional Patterns and Transitions. Population and Development Review. 1993;19(1):138–57.

5. Agyei-Mensah S, de-Graft Aikins A. Epidemiological Transition and the Double Burden of Disease in Accra, Ghana. J Urban Health. 2010 Sep;87(5):879–97.

6. Andam KS, Tschirley D, Asante SB, Al-Hassan RM, Diao X. The transformation of urban food systems in Ghana: Findings from inventories of processed products. Outlook Agric. 2018 Sep;47(3):233–43.

7. Bosu WK. An overview of the nutrition transition in West Africa: implications for non-communicable diseases. Proc Nutr Soc. 2015 Nov;74(4):466–77.

8. Ahmed A, Lazo DPL, Alatinga KA, Gasparatos A. From Ampesie to French fries: systematising the characteristics, drivers and impacts of diet change in rapidly urbanising Accra. Sustain Sci [Internet]. 2022 Aug 16 [cited 2023 Jun 23]; Available from: https://link.springer.com/10.1007/s11625-022-01195-y

9. Meng T, Florkowski WJ, Sarpong DB, Chinnan MS, Resurreccion AVA, Meng T, et al. Consumer’s Food Shopping Choice in Ghana: Supermarket or Traditional Outlets? 2014 [cited 2023 Jun 23]; Available from: https://ageconsearch.umn.edu/record/164600

10. Akyeampong E. Indigenous Knowledge and Maritime Fishing in West Africa: the Case of Ghana. In: Boon E, Hens L, editors. Indigenous Knowledge Systems and Sustainable Development: Relevance for Africa. Delhi: Kamla-Raj Enterprises; 2007.

11. Colecraft E, Marquis GS, Aryeetey R, Sakyi-Dawson O, Lartey A, Ahunu B, et al. Constraints on the Use of Animal Source Foods for Young Children in Ghana: A Participatory Rapid Appraisal Approach. Ecology of Food and Nutrition. 2006 Oct;45(5):351–77.

12. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana's evolving protein economy. Food Security. 2016;8(5):909–20.

13. Overå R, Atter A, Amponsah S, Kjellevold M. Market women's skills, constraints, and agency in supplying affordable, safe, and high-quality fish in Ghana. Maritime Studies. 2022 Dec;21(4):485–500.

14. Kawarazuka N, Bene C. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutr. 2011;14(11):1927–38.

15. Ministry of Food and Agriculture and University of Ghana School of Public Health. Food-Based Dietary Guidelines [Internet]. 2023. Available from: https://mofa.gov.gh/site/images/pdf/Ghana_Food_Based_Dietary_Guidelines_2023.pdf

16. Ministry of Fisheries & Aquaculture Development. National Fisheries Management Plan- A National Policy for the Management of the Marine Fisheries Sector 2015-2019 [Internet]. 2015. Available from: https://www.crc.uri.edu/download/GH2014_POL005_FC_FisheriesMgtPlan2016.pdf

17. Atta-Mills J, Alder J, Rashid Sumaila U. The decline of a regional fishing nation: The case of Ghana and West Africa. Natural Resources Forum. 2004 Feb;28(1):13–21.

18. Ameyaw AB, Breckwoldt A, Reuter H, Aheto DW. From fish to cash: Analyzing the role of women in fisheries in the western region of Ghana. Marine Policy. 2020 Mar;113:103790.

19. Torell E, Bilecki D, Owusu A, Crawford B, Beran K, Kent K. Assessing the Impacts of Gender Integration in Ghana's Fisheries Sector. Coastal Management. 2019 Nov 2;47(6):507–26.

20. Lazar N, Yankson K, Blay J, Ofori-Danson P, Markwei P, Agbogah K, et al. Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018. Report No.: GH2014_SCI042_CRC.

21. Bank of Ghana. The fishing sub-sector and Ghana's economy [Internet]. Accra, Ghana: Research Department of Bank of Ghana; 2008. Available from: https://www.bog.gov.gh/wp-content/uploads/2019/07/fisheries_completerpdf.pdf

22. FAO. Fishery and Aquaculture Country Profiles. Ghana, 2016. Rome: Fisheries and Aquaculture Division; 2023.

23. Ministry of Food and Agriculture. Medium term agricultural sector investment plan (METASIP) II, 2014-2017 [Internet]. Accra, Ghana: Ministry of Food and Agriculture; 2015. Available from: https://faolex.fao.org/docs/pdf/gha174314.pdf

24. Ministry of Food and Agriculture, Fisheries Commission. Ghana National Aquaculture Development Plan (GNADP) [Internet]. Accra, Ghana: Ministry of Food and Agriculture; 2012. Available from: https://faolex.fao.org/docs/pdf/gha149443.pdf

25. Ragasa C, Andam KS, Asante SB, Amewu S. Can local products compete against imports in West Africa? Supply- and demand-side perspectives on chicken, rice, and tilapia in Ghana. Global Food Security. 2020;26.

26. Ragasa C, Agyakwah SK, Asmah R, Mensah ETD, Amewu S, Oyih M. Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana. Aquaculture. 2022 Jan;547:737476.

27. Bogard JR, Farook S, Marks GC, Waid J, Belton B, Ali M, et al. Higher fish but lower micronutrient intakes: Temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh. PLoS One. 2017;12(4):e0175098.

28. Ayuya OI, Soma K, Obwanga B. Socio-Economic Drivers of Fish Species Consumption Preferences in Kenya's Urban Informal Food System. Sustainability. 2021 May 8;13(9):5278.

29. Mockshell J, Asante-Addo C, Andam KS, Asante F. Transitioning to nutrition-sensitive food environments in Ghana: Triple sector strategies to reduce the triple burden of malnutrition. 2021;52.

30. Berkum S van, Dengerink J, Ruben R. The food systems approach: sustainable solutions for a sufficient supply of healthy food. Vol. 538076. The Hague: Wageningen Economic Research; 2018.

31. Creswell J. Qualitative inquiry and research design: Choosing among five approaches. Thousand Oaks, CA: Sage; 2013.

32. Guest G, Bunce A, Johnson L. How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. Field Methods. 2006 Feb;18(1):59–82.

33. Kwakye-Opong R. Clothing and Colour Symbolisms in the Homowo Festival: A means to Sociocultural Development. Research on Humanities and Social Sciences. 2014;4(13):112–25.

34. Pelto GH, Armar-Klemesu M. Balancing nurturance, cost and time: complementary feeding in Accra, Ghana. Matern Child Nutr. 2011;7 Suppl 3(s3):66–81.

35. Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006 Jan;3(2):77–101.

36. Afoakwah R, Osei MBD, Effah E. A Guide on Illegal Fishing Activities in Ghana [Internet]. Narragansett, RI, USA: USAID/Ghana Sustainable Fisheries Management Project. Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island & University of Cape Coast, Ghana; 2018. Report No.: GH2014_SCI048_UCC. Available from: https://www.crc.uri.edu/download/GH2014_SCI048_UCC_FIN508.pdf

37. Onumah EE, Quaye EA, Ahwireng AK, Campion BB. Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. Sustainability. 2020;12(19):7932.

38. Codjoe SNA, Owusu G, Burkett V. Perception, experience, and indigenous knowledge of climate change and variability: the case of Accra, a sub-Saharan African city. Reg Environ Change. 2014 Feb;14(1):369–83.

39. Pardie PP, Campion BB. The how in fishing and fish processing: traditional artisanal fishing and fish processing practices among the Ga people of Ghana. Maritime Studies. 2022 Dec;21(4):501–17.

40. Heinbuch U. Animal protein sources for rural and urban populations in Ghana. Cotonou, Benin: Programme for the Integrated Development of Artisanal Fisheries in West Africa; 1994 p. 25. Report No.: IDAF/WP/58.

41. Quagrainie KK, Chu J. Determinants of Catch Sales in Ghanaian Artisanal Fisheries. Sustainability. 2019 Jan 9;11(2):298.

42. Rooney MS, Arku RE, Dionisio KL, Paciorek C, Friedman AB, Carmichael H, et al. Spatial and temporal patterns of particulate matter sources and pollution in four communities in Accra, Ghana. Science of The Total Environment. 2012 Oct;435–436:107–14.

43. Tiwaah Amoah Y, Hardi B, Beran K, The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Understanding the flow of fish: A scoping visit to Northern Ghana. Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and MOFAD,; 2015 p. 25.

44. Galbete C, Nicolaou M, Meeks KA, de-Graft Aikins A, Addo J, Amoah SK, et al. Food consumption, nutrient intake, and dietary patterns in Ghanaian migrants in Europe and their compatriots in Ghana. Food Nutr Res. 2017;61(1):1341809.

45. Pradeilles R, Irache A, Wanjohi MN, Holdsworth M, Laar A, Zotor F, et al. Urban physical food environments drive dietary behaviours in Ghana and Kenya: A photovoice study. Health & Place. 2021 Sep;71:102647.

46. Gamor G, Akoto-Danso EK, Karg H, Chagomoka T. Traditional Recipes from the Northern Region of Ghana [Internet]. AVDRC - The World Vegetable Center; 2015. Available from: https://avrdc.org/download/publications/recipes/ghana-cook-book_final_web.pdf

47. Omari R, Jongerden J, Essegbey GO, Frempong G, Ruivenkamp G. Fast Food in the Greater Accra Region of Ghana: Characteristics, Availability and the Cuisine Concept. Food Studies. 1(4):29–44.

48. Liguori J, Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, et al. Individual-level drivers of dietary behaviour in adolescents and women through the reproductive life course in urban Ghana: A Photovoice study. Maternal & Child Nutrition [Internet]. 2022 Oct [cited 2023 Jun 23];18(4). Available from: https://onlinelibrary.wiley.com/doi/10.1111/mcn.13412

49. Abizari AR, Ali Z. Dietary patterns and associated factors of schooling Ghanaian adolescents. J Health Popul Nutr. 2019;38(1):5.

50. Abubakari A, Jahn A. Maternal Dietary Patterns and Practices and Birth Weight in Northern Ghana. PLoS One. 2016;11(9):e0162285.

51. Galbete C, Nicolaou M, Meeks K, Klipstein-Grobusch K, de-Graft Aikins A, Addo J, et al. Dietary patterns and type 2 diabetes among Ghanaian migrants in Europe and their compatriots in Ghana: the RODAM study. Nutr Diabetes. 2018;8(1):25.

52. Kubuga CK, Kennedy G, Song WO. Food-based indicators are related to iron and iodine deficiencies of mother-toddler dyads during the lean season in northern Ghana. Br J Nutr. 2020;1–10.

53. Ogum Alangea D, Aryeetey RN, Gray HL, Laar AK, Adanu RMK. Dietary patterns and associated risk factors among school age children in urban Ghana. BMC Nutr. 2018;4:22.

54. Quansah DY, Boateng D. Maternal dietary diversity and pattern during pregnancy is associated with low infant birth weight in the Cape Coast metropolitan hospital, Ghana: A hospital based cross-sectional study. Heliyon. 2020;6(5):e03923.

55. Ghartey AB. Nutrition Policy and Programs in Ghana: The limitation of a single sector approach [Internet]. Washington, DC: The International Bank for Reconstruction and Development / The World Bank; 2011. (HNP Discussion Paper). Report No.: 69370. Available from: https://documents1.worldbank.org/curated/en/540101467990381054/pdf/693700WP0P1040 0tritionPolicyDPMenno.pdf

56. Christian AK, Marquis GS, Colecraft EK, Lartey A, Sakyi-Dawson O, Ahunu BK, et al. Caregivers' nutrition knowledge and attitudes are associated with household food diversity and children's animal source food intake across different agro-ecological zones in Ghana. Br J Nutr. 2016 Jan 28;115(2):351–60.

57. Nsiah-Asamoah C, Pereko KKA, Intiful FD. Nutritional counselling interactions between health workers and caregivers of children under two years: observations at selected child welfare clinics in Ghana. BMC Health Serv Res. 2019 Dec;19(1):817.

58. Sandow A, Tice M, Pérez-Escamilla R, Aryeetey R, Hromi-Fiedler AJ. Strengthening Maternal, Infant, and Young Child Nutrition Training and Counseling in Ghana: A Community-Based Approach. Current Developments in Nutrition. 2022 Sep;6(9):nzac127.

59. Parbey P, Aryeetey R, University of Ghana. A review of food and nutrition communication and promotion in Ghana. AJFAND. 2022 Apr 4;22(2):19602–23.

60. Stołyhwo A, Sikorski ZE. Polycyclic aromatic hydrocarbons in smoked fish – a critical review. Food Chemistry. 2005 Jun;91(2):303–11.

61. European Commission. Commission Regulation (EU) No. 835/2011 of 19 August 2011 amending Regulation (EC) No. 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs. 2011.

62. International Association of Fish Inspectors. Statement from the International Association of Fish Inspectors on the safety of smoked fishery products. Reykiavik, Iceland: World Seafood Congress; 2017.

63. Bomfeh K, Jacxsens L, De Meulenaer B, Amoa-Awua WK, Afoakwa EO. Policy recommendations and smallholder guidelines for improved fish smoking systems. FAO Fisheries and Aquaculture Circular. 2019;(C1178).

64. Hasselberg AE, Aakre I, Scholtens J, Overå R, Kolding J, Bank MS, et al. Fish for food and nutrition security in Ghana: Challenges and opportunities. Global Food Security. 2020;26:100380.

65. Huang J, Nkrumah PN, Anim DO, Mensah E. E-Waste Disposal Effects on the Aquatic Environment: Accra, Ghana. In: Whitacre DM, editor. Reviews of Environmental Contamination and Toxicology [Internet]. Cham: Springer International Publishing; 2014 [cited 2023 Jun 24]. p. 19–34. (Reviews of Environmental Contamination and Toxicology; vol. 229). Available from: http://link.springer.com/10.1007/978-3-319-03777-6_2

66. Amoyaw-Osei Y, Agyekum OO, Pwamang JA, Mueller E, Fasko R, Schluep M. Ghana e-Waste Country Assessment [Internet]. SBC e-Waste African Project; 2011. Available from: https://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/E-wasteAssessmentGhana.pdf

67. Steinhausen SL, Agyeman N, Turrero P, Ardura A, Garcia-Vazquez E. Heavy metals in fish nearby electronic waste may threaten consumer’s health. Examples from Accra, Ghana. Marine Pollution Bulletin. 2022 Feb;175:113162.

68. Babut M, Sekyi R, Rambaud A, Potin-Gautier M, Tellier S, Bannerman W, et al. Improving the environmental management of small-scale gold mining in Ghana: a case study of Dumasi. Journal of Cleaner Production. 2003 Mar;11(2):215–21.

69. Gbogbo F, Otoo SD, Huago RQ, Asomaning O. High levels of mercury in wetland resources from three river basins in Ghana: a concern for public health. Environ Sci Pollut Res. 2017 Feb;24(6):5619–27.

70. Donkor AK, Bonzongo JC, Nartey VK, Adotey DK. Mercury in different environmental compartments of the Pra River Basin, Ghana. Science of The Total Environment. 2006 Sep;368(1):164–76.

71. Oppong SOB, Voegborlo RB, Agorku SE, Adimado AA. Total Mercury in Fish, Sediments and Soil from the River Pra Basin, Southwestern Ghana. Bull Environ Contam Toxicol. 2010 Sep;85(3):324–9.

72. Asare-Donkor NK, Adimado AA. Influence of mining related activities on levels of mercury in water, sediment and fish from the Ankobra and Tano River basins in South Western Ghana. Environ Syst Res. 2016 Dec;5(1):5.

73. Debrah CA, Ribeiro PF, Baah D. Total Levels of Mercury Concentrations in Marine Fish - Kumasi, Ghana. EJNFS. 2020 Nov 10;81–6.

74. Kwaansa-Ansah EE, Agorku SE, Nriagu JO. Levels of Total Mercury in Different Fish Species and Sediments from the Upper Volta Basin at Yeji in Ghana. Bull Environ Contam Toxicol. 2011 Apr;86(4):406–9.

75. Ntow WJ, Khwaja MA. Mercury pollution in Ghana (West Africa) coastal commercial fish. Environmental Technology Letters. 1989 Jan;10(1):109–16.

76. Voegborlo R, Adimado A. Total Mercury Distribution in Different Fish Species Representing Different Trophic levels from the Atlantic Coast of Ghana. Jnl Sci Tech [Internet]. 2010 Apr 20 [cited 2023 Jun 24];30(1). Available from: http://www.ajol.info/index.php/just/article/view/53933

77. Voegborlo RB, Matsuyama A, Adimado AA, Akagi H. Determination of methylmercury in marine and freshwater fish in Ghana using a combined technique of dithizone extraction and gas–liquid chromatography with electron capture detection. Food Chemistry. 2011 Feb;124(3):1244–8.

78. Otchere FA, Joiris CR, Holsbeek L. Mercury in the bivalves Anadara (Senilia) senilis, Perna perna and Crassostrea tulipa from Ghana. Science of The Total Environment. 2003 Mar;304(1–3):369–75.

79. Voegborlo RB, Adimado AA, Ephraim JH. Total Mercury Distribution in Different Tissues of Frigate Tuna (Auxis thazard thazard) from the Atlantic Coastal Waters of Ghana, Gulf of Guinea. Environ Monit Assess. 2007 Sep;132(1–3):503–8.

80. Feglo P, Frimpong E, Essel-Ahun M. Salmonellae carrier status of food vendors in Kumasi, Ghana. E Af Med Jrnl. 2004 Oct 22;81(7):358–61.

81. Plahar WA, Nerquaye-Tetteh GA, Annan NT. Development of an integrated quality assurance system for the traditional Sardinella sp. and anchovy fish smoking industry in Ghana. Food Control. 1999 Feb;10(1):15–25.

82. Adegunwa MO, Adebowale AA, Olisa ZG, Bakare HA. Chemical and microbiological qualities of smoked herring (sardinella eba,valenciennes 1847) in Odeda, Ogun state, Nigeria. International Journal of Microbiology Research and Reviews. 2013;1(5):85–7.

83. Likongwe MC, Kasapila W, Katundu M, Mpeketula P. Microbiological quality of traditional and improved kiln smoked catfish (*Clarias gariepinus* ; Pisces; Clariidae) in Lake Chilwa Basin. Food Sci Nutr. 2019 Jan;7(1):281–6.

84. Akinwumi FO, Adegbehingbe KT. Microbiological analysis of three of smoked fish obtained from the Ondo State, Nigeria. Food and Public Health. 2015;5(4):122–6.

85. Ikutegbe V, Sikoki F. Microbiological and biochemical spoilage of smoke-dried fishes sold in West African open markets. Food Chemistry. 2014 Oct;161:332–6.

86. Owusu V, Adu-Boahen K, Kyeremeh S, Demalie I, Eshun P. Factors influencing compliance of closed fishing season: lessons from small-scale coastal fisheries in the Central Region of Ghana. Humanit Soc Sci Commun. 2023 Jan 17;10(1):20.

87. Bortei-Doku Aryeetey E. Kinsfolk and Workers: Social Aspects of Labor Relations Among Ga-Dagme Coastal Fisherfolk. In: Dynamics and Use of Sardinella Resources from Upwellling off Ghana and Ivory Coast: Acts of DUSRU Meeting [Internet]. Paris: ORSTROM; p. 134–51. Available from: https://hdl.handle.net/10535/5780

88. Akuffo A S, Quagrainie KK, Obirikorang KA. Analysis of the determinants of fish consumption by households in Ghana. Aquaculture Economics & Management. 2020;24(3).

89. Osei AAA, Etuah S, Aidoo R, Fialor SC, Adams F. Drivers of smoked marine fish prices and challenges along the value chain. IJSE. 2023 Feb 3;50(2):242–59.

90. Osei-Asare YB, Eghan M. Food price inflation and consumer welfare in Ghana. international Journal of Food and Agricultural Economics. 2013;1(1):27–39.

91. Pacem K. To what extent do household expenditure and prices affect the demand for rice in northern Ghana? 2018; Available from: https://ageconsearch.umn.edu/record/266570/

92. Ansah IGK, Marfo E, Donkoh SA. Food demand characteristics in Ghana: An application of the quadratic almost ideal demand systems. Scientific African. 2020;8:e00293.

93. Akpalu W, Okyere MA. Fish Protein Transition in a Coastal Developing Country. Environ Resource Econ. 2023 Mar;84(3):825–43.

94. Dey MM, Garcia YT, Praduman K, Piumsombun S, Haque MS, Li L, et al. Demand for fish in Asia: a cross-country analysis*. Australian Journal of Agricultural and Resource Economics. 2008;52(3):321–38.

95. Dey MM, Alam MdF, Paraguas FJ. A Multistage Budgeting Approach to the Analysis of Demand for Fish: An Application to Inland Areas of Bangladesh. Marine Resource Economics. 2011 Mar;26(1):35–58.

96. Apetorgbor S. Closed Season Brief. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018 p. 10. Report No.: GH2014_POL109_CRC.

97. Coastal Resources Center. Resources for Revising Ghana's Fisheries Act [Internet]. Narragansett, RI, USA: The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; p. 195. Report No.: GH2014_POL114_CRC. Available from: https://pdf.usaid.gov/pdf_docs/PA00XK9C.pdf

98. Ghana Statistical Service. Population of Regions and Districts [Internet]. Ghana Statistical Service; 2021. (Ghana 2021 Population and Housing Census). Report No.: Volume 3A. Available from: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf

2.8 Tables and figures

Table 2.1: Semi-structured interview questions.

- What are the main reasons why you eat fish and seafood?
- What kinds of fish and seafood do you usually eat? Never eat?
- From where do you get your fish and seafood? Where do you avoid?
- Who eats fish and seafood in your household? Is your household similar to other households?
- What problems need solving regarding fish and seafood?

Table 2.2. Sociodemographic characteristics of the interviewee sample.

	Neighborhood income level		
	Low-income, *n* = 10	**Middle-income, *n* = 9**	**High-income, *n* = 10**
Accra native, *n*	8	8	6
Ethnicity, *n*			
Akan	4	3	5
Ga-Dangme	6	6	5
Education level, *n*			
< High school	2	2	1
> Some high school	8	7	8
Other	0	0	1
Age, *n*			
18-29 years	1	2	3
30-39 years	3	1	1
40-55 years	2	3	6
55+ years	4	4	0

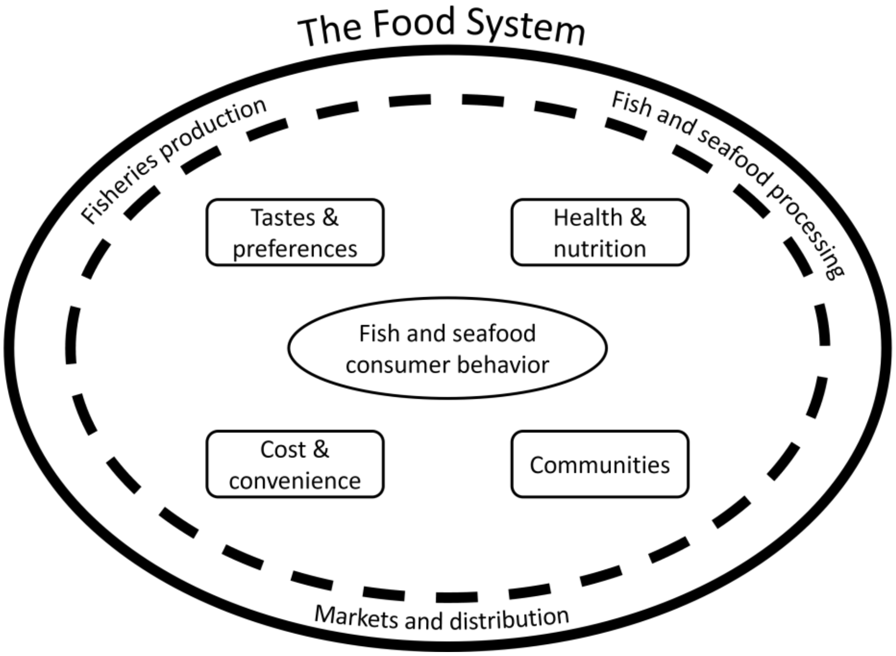

Figure 2.1: Conceptual framework for themes mediating linkages between consumer behavior toward fish and seafood and the broader food system.

Chapter 3 The Roles of Fish and Seafood in Patterns of Household Food Expenditure and Their Socioeconomic Determinants in Ghana

3.1 Introduction

Fish and seafood is an important component of African diets, where it comprises a significant fraction of total animal protein consumed (1). In addition to protein, fish are seafood are composed of essential nutrients that promote health across the lifespan, such as omega-3 polyunsaturated fatty acids (2), iron, zinc, and iodine (3–6).

In lower socioeconomic settings, fish and seafood consumption is regarded as an appropriate strategy to prevent or mitigate undernutrition (7–9). As a nutrient-dense food, fish and seafood can fill important gaps in the nutrient intake of reproductive age women and children, especially small indigenous species that are often consumed whole (6–8,10). In higher socioeconomic settings, fish and seafood is recommended to prevent or mitigate overnutrition. A classic study of the Mediterranean diet, which characterizes higher than average fish and seafood consumption as a beneficial dietary component, found that greater adherence was protective against risk of coronary heart disease, cancer deaths, and total mortality in a large cohort of adults living in Greece (11). Despite the role of fish and seafood in healthy diets (12), the overall pattern of food-related behaviors may be more impactful in affecting health and nutrition outcomes.

Historically, societies undergo a nutrition transition from low variety diets of cereals, fruits, and vegetables to higher variety diets heavily composed of processed foods (13). This transition runs parallel to maternal and child undernutrition giving way to overweight and obesity across the life course. Previous research evidences this nutrition transition in Ghana, a lower-middle income West African country, by characterizing two distinct patterns of food-related behaviors that both contain fish: a ‘traditional’ diet pattern comprised of unrefined starchy staples, fruits, vegetables, nuts, legumes, and fish; and a ‘modern’ diet pattern of refined grains, red meat, poultry, eggs, fish, dairy, sugary or salty snacks, sugar-sweetened beverages, and caffeinated beverages (14–21). Furthermore, epidemiologic evidence suggests a triple burden of malnutrition, or undernourishment, overnutrition, and micronutrient deficiencies, occurring in Ghana at the same time (22).

Fish and seafood consumption could be a viable food-based strategy to address Ghana’s triple burden of malnutrition. Previous research suggests that fish and seafood is highly consumed, as it appears in both Ghanaian ‘traditional’ and ‘modern’ patterns of food-related behaviors (14–16,19–21,23) and contributes over 60% of total household expenditures on animal protein in Ghana (24). Moreover, fish and seafood is recognized as part of a healthy diet in Ghana’s food-based dietary recommendations by contributing to protein intake and protecting against cardiovascular disease (25). However, fish and seafood consumption can depend on consumer factors, such as poverty status, rurality, and region of residence (24,26), or preferences for different types of fish (27,28). Most of the previous diet pattern research in Ghana focuses on single subpopulations defined by one gender, life stage, or physical location, thereby limiting generalizability for effective comparison of results. Furthermore, this research tends to aggregate fish and seafood into a single broad food group, thereby ignoring biodiversity consumed in Ghana (28). This biodiversity can be tied to variation in important consumer factors, such as price and consumer preferences (28,29). Importantly, the nutrient composition of fish and seafood can differ by marine or freshwater origin and species/genera, such that larger farmed freshwater fish are much less nutrient dense than smaller wild caught marine fish that are consumed whole (4,30). Therefore, more comprehensive research that aims to understand the roles of different types of fish in diets across Ghana's population is vital for developing national food and nutrition policies that prioritize those vulnerable to different types of malnutrition.

The objectives of this study were to identify the dominant patterns of food-related behaviors among households in Ghana, assess which patterns include fish and seafood, and explore the relationships of each pattern with a range of potential sociodemographic, economic, and environmental determinants. We also conducted a sensitivity analysis to assess whether disaggregating fish and seafood into species/genera changed the nature of those patterns and their relationships with the potential determinants. We used household-level food expenditure data as a proxy for individual-level dietary data by using the adult equivalent approach to divide food acquisition among members according to their energy requirements (31,32). Our hypotheses were that 'traditional' and 'modern' food-related behavior patterns would emerge, that fish and seafood would be significant components of both patterns, but that each pattern would be comprised of different species/genera.

3.2 Methods

3.2.1 Study design and population

The seventh round of the Ghana Living Standards Survey, or the GLSS 7, is a cross-sectional household-level survey that was conducted by the Ghana Statistical Service with technical and financial support from the Government of Ghana, UKAid, the Dutch Government, and The World Bank (GSS, 2018). The overarching purpose of the GLSS is to collect sociodemographic data on education, health, housing, food and non-food consumption expenditure, and employment, among other topics. The GLSS is conducted approximately every five years with each round focusing on a specific topic. The seventh round of the survey focused on agriculture (33).

Data were collected by trained interviewers. Households were defined as individuals who live together in the same unit and share housekeeping and cooking arrangements. The total sample the GLSS 7 comprised 14,009 households drawn from 1,000 enumeration areas divided proportionally by urban or rural status and Ghana’s ten administrative regions to achieve national representativeness. Data collection took place over 12 months from October 2016 to September 2017 (33).

3.2.2 Household food expenditure

Household food expenditure was assessed during six household visits during a one-month period using a combination of self- and interviewer-administered survey tools (33). Between survey visits, one literate household member recorded diaries of daily food and non-food expenditures. Then, trained interviewers reviewed these diaries with the household member responsible for household purchases against a predefined list of frequently purchased food items.

In line with the agricultural focus of the GLSS 7, interviewers used a detailed food list of 304 individual food items including cereal and grain products, animal source foods, fruits and vegetables, a variety of beverages, oils and seasonings, and food away from home (34). For this study, we aggregated the 306 food items into 29 food groups using a two-step approach. In the first step, we condensed some food groups already described in the GLSS 7 food list where we found significant overlap in economic or culinary purpose. Some examples are combining two GLSS 7 food groups, ‘corned beef’ and ‘sausage’, into one ‘processed meat’ group; combining freshwater fish items, marine fish items, and shellfish items with three separate tinned fish food groups into one ‘fish and seafood’ food group; and combining local and foreign brands of rice into one ‘rice’ group. In the second step, we disaggregated some of the GLSS 7 food list groups to align with the food groups developed for the Minimum Dietary Diversity for Women (MDD-W) indicator. Since the purpose of the MDD-W index is to monitor nutrient adequacy (individual-level consumption of fewer than five food groups has been shown to be associated with nutrient inadequacy for a reproductive age woman) (35), using the MDD-W indicator ensures meaningful incorporation of nutrition principles into the GLSS 7 household-level food expenditure data. Specifically, we combined sweetened and unsweetened dairy products and fresh milk into one food group, categorized fruits and vegetables into food groups that reflect their higher or lower vitamin A content, and combined white roots, tubers, and plantains.

We then created a suite of new variables that describe monthly household food expenditure per adult equivalent, which has been previously used as an imperfect proxy for individual-level food consumption (31). First, we added the six assessments of household expenditure on each food item and divided that sum by the number of adult equivalents in the household. The adult equivalent scale came predefined in the GLSS 7, which we presumed followed the GLSS 6 methodology of measuring an adult equivalent based on the lower calorie requirements of infants and children (36). Food items were aggregated into 29 food groups informed by the survey tool and their nutrition profile. Household food expenditure was recorded in the national currency, Ghanaian cedis.

3.2.3 Assessment of sociodemographic, economic, and environmental characteristics

Interviewers collected data on household sociodemographic, economic, and environmental characteristics. From these data, we constructed variables representing the head of the household’s age, sex, religion, and ethnicity, whether the household included a pregnant person or children aged under 5 years at the time of being surveyed, and the number of adult equivalents in the household. For head of household religion, we aggregated nine religious denominations into three categories: Traditionalist, Christian, and Muslim. Similarly, for head of household ethnicity, we aggregated 58 ethnicities into nine categories that match the Ghana Statistical Service's summary reporting of the GLSS 7 (33).

Economic characteristics comprised head of household educational attainment, household participation in fisheries or livestock ownership, and total monthly household income per adult male equivalent. Head of household educational attainment was defined as attaining or not a secondary education level. Household participation in fisheries was defined as fishing, fish farming, or fish processing in the last 12 months by any household member. Similarly, household livestock ownership was created as a dichotomous variable defined as any household member having owned or not any draught animals, cattle, ruminants, poultry, or grasscutters in the last 12 months. In line with Deaton & Grosh (2000) and Azzarri et al. (2015), total monthly household income per adult male equivalent was defined using the proxy measure of total monthly household expenditure, which was divided by the number of adult equivalents in the household and transformed on a logarithmic scale (37,38).

Environmental characteristics included the household's rural status, region, agroecological zone, and survey quarter. Survey quarters were defined as three-month periods (January to March, April to June, July to September, and October to December) that were used to conceptually represent food or other price inflation, seasons, and special occasions (26).

3.2.4 Identification of food expenditure patterns

Principal component analysis (PCA), a popular method in the diet pattern literature (39–41), was used to identify patterns among the food expenditure data. When applied, PCA identifies linear correlations between different variables to reduce many down to a few with the purpose of explaining as much variance as possible in the data (42). Here, we used PCA to assess how spending on multiple food groups were correlated. These correlations were rotated orthogonally and extracted as new, uncorrelated index variables representing food groups that are often or seldomly purchased together.

Several criteria and guidelines were applied to guide decision-making on the number of index variables, or food expenditure patterns, to extract. These criteria and protocols included: 1.) the index variable's eigenvalue was greater than or equal to 1.00; 2.) the index variable comprised two or more food groups with factor loadings greater than or equal to |0.30|; 3.) assessing where the marginal gain in explained variance was insignificant by examining the scree plot for a break; and 4.) interpreting the extent to which the index variable was a realistic food expenditure pattern (for example, factors comprising only condiments and beverages were discarded).

Principal component analysis identified a multitude of principal components or index variables, to which we applied our extraction criteria. We then calculated a score for each household that summed all food expenditure by food group and weighed them by their factor loadings, or the correlations between component and variable (42). This score indicates the relative contribution of each food group to each food expenditure pattern, thereby describing how closely each household adhered to each pattern.

3.2.5 Statistical analysis

Data cleaning and statistical analysis was conducted on 12,738 households with complete data using Stata SE version 17.0 (StataCorp, College Station, TX, USA). We accounted for the complex survey design by identifying regional and urban/rural strata and applying the programmed survey weights. We calculated means and proportions for household-level sociodemographic, economic, and environmental characteristics by female-headed household status and rurality. Bivariate associations between household-level characteristics and quintiles of the expenditure pattern scores were calculated using the ANOVA test for continuous variables and Rao-Scott chi-square test for categorical variables.

We then used multivariate regression analysis to identify the household-level characteristics associated with scores of adherence to each extracted food expenditure pattern. We removed one covariate, agroecological zone, as its variance inflation factor suggested collinearity with other variables. We also reviewed the data for potential influential observations and outliers, but we found highly similar results when they were removed. Thus, all data were retained for final models. In a supplementary analysis, we repeated this procedure to identify household-level characteristics that were associated with log-transformed household food expenditure on fish and seafood.

3.2.6 Sensitivity analysis

We conducted a sensitivity analysis to assess whether disaggregating one fish and seafood group into species/genera influenced the food expenditure patterns extracted in the main analysis and the relationships they exhibited with potential socioeconomic determinants. In the first stage of the sensitivity analysis, we disaggregated the single fish and seafood group into four smaller groups that incorporated two components of biodiversity: population/species and community/ecosystem (43). The freshwater fish group included tilapia and river fish; marine fish included herring and mackerel; and shellfish included shrimp, crab, and snail. A fourth other fish and seafood group included the fish and seafood items we could not determine to be of freshwater or marine origin or classified as shellfish. This group comprised write-in responses with insufficient detail (for example, ‘fresh fish’ or ‘fish powder’), responses with more than one fish and seafood item (for example, ‘smoked lungfish and tuna’), or local names that could not be matched to scientific names (44). At the second level of disaggregation, we separated these four food groups into the most species/genera possible. For example, we disaggregated shellfish into individual shrimp, crab, and snail, but we combined brands of tinned mackerel with fresh mackerel. At each level of disaggregation, we used PCA to develop food expenditure patterns and the same approach as the main analysis to identify household-level characteristics that are associated with scores of adherence to each extracted pattern.

3.3 Results

3.3.1 Study population

Potential household-level sociodemographic, economic, and environmental determinants of Ghanaian food expenditure patterns are presented in Table 3.1. The mean head of household age was 45.1 years (SD, 15.5 years), with more than one-third of households having female heads. Female-headed households were generally older, more likely to be Christian, and more likely to belong to the Akan ethnic group than male-headed households. They also tended to have smaller household sizes in number of adult equivalents and were less likely to have a pregnant female or one or more children under five years old. While female-headed households were less educated, they earned nearly 9% more monthly income per adult equivalent. Female-headed households were less likely to have owned livestock or harvested crops in the past 12 months but showed a similar prevalence of fisheries participation as male-headed households. Compared to urban households, rural households tended to have a higher household size in adult equivalents and were more likely to have a pregnant female or one or more children under five years old. Rural households were less educated and earned nearly half the monthly income per adult equivalent as urban households. While rural households were much more likely to own livestock and harvest crops, they also showed equal levels of fisheries participation.

At the national level, monthly expenditure on fish and seafood was 33.4 cedis per household member. Over two-thirds of total animal source food expenditure was on fish and seafood (67.5%), a marked increase than the 61% figure calculated from the sixth round of the GLSS collected in 2012 and 2013 (24). Among 13 types of fish and seafood gleaned from the GLSS 7 survey, households purchased an average of 3.8 distinct types in the past month. Of households that purchased fish and seafood, the highest proportions of total fish expenditure were mackerel (26.4%) and herring (20.8%), followed by other freshwater fish (14.5%), which largely comprised catfish. There were considerable differences in fish and seafood expenditure by head of household sex and rurality. Female-headed households spent over 50% more on fish and seafood than male-headed households (43.1 and 28.2 cedis, respectively). The proportion of fish and seafood expenditure was much higher among rural households (75.2%) than urban households (61.6%). Male-headed and rural households consumed 3.5 types of fish and seafood compared to female-headed and urban households (4.0 and 4.3, respectively).

3.3.2 Exploratory food expenditure patterns

We conducted PCA in 12,738 households with complete food expenditure and socioeconomic data, which yielded three patterns that explained 25.8% of the total variance in food expenditure (presented in Table 3.2). The first food expenditure pattern, called ‘Traditional’, exhibited strong positive correlations with household expenditure on fish and seafood, vitamin A-rich fruit, dark green leafy vegetables, other vegetables, and white roots and plantains. Red meat and vitamin A-rich vegetables also exhibited positive correlations, but their factor loadings only approached the inclusion threshold of greater than 0.30 or less than -0.30.

The ‘Traditional’ pattern explained 10.1% of the total variance in food expenditure. The second food expenditure pattern, called ‘Processed foods’, exhibited strong positive correlations with processed grain products, milk, sweets, and coffee, tea, and cocoa drinks. This pattern was also correlated with processed meat and other fruit, but their factor loadings did not meet the factor loading threshold. The ‘Processed foods’ pattern explained 9.5% of the total variance in food expenditure. The third pattern, called ‘Food away from home (FAFH)’, exhibited strong positive correlations with food away from home, a food group comprising mixed dishes purchased at canteens, restaurants, or hotels, water, and alcoholic beverages. The ‘FAFH’ pattern explained 6.2% of the total variance in food expenditure.

3.3.3 Sociodemographic, economic, and environmental characteristics of the GLSS 7 households across quintiles of food expenditure patterns

In Table 3.3, we present the sociodemographic, economic, and environmental characteristics of the GLSS 7 households across quintiles representing increasing adherence to the three extracted food expenditure patterns using the baseline food groups. Heads of households were older in higher quintiles of the ‘Traditional’ food expenditure pattern, but younger in higher quintiles of the ‘Processed foods’ and ‘Food away from home’ patterns. Female-headed households were more prevalent in higher quintiles of the ‘Traditional’ and ‘Processed foods’ patterns, but less prevalent in the ‘Food away from home’ patterns. Households with more than one child under five years of age and whose heads attained secondary education were more prevalent in higher quintiles of the ‘Processed foods’ and ‘Food away from home’ patterns.

3.3.4 Sociodemographic, economic, and environmental determinants of adherence to food expenditure patterns

We assessed associations between potential sociodemographic, economic, and environmental determinants and adherence to the identified food expenditure patterns. The results of multivariate linear regression models are presented in Table 3.4. Adherence to the 'Traditional' pattern was associated with head of household age, female sex, religion, and secondary educational attainment, pregnant household member, one or more household members under 5y, household member harvested crops in the past 12mo, monthly household income per adult equivalent, rural status, and region of residence. These determinants explained 33.1% of the variance in the 'Traditional' expenditure pattern score. Adherence to the 'Processed foods' pattern was associated with head of household age, female sex, religion, and secondary educational attainment, household size, one or more household members under 5y, crop harvest in the past 12mo, household income, and region. These determinants explained 36% of the variance in the 'Processed foods' pattern score. Finally, adherence to the 'FAFH' pattern was associated with head of household age, female sex, religion, and ethnicity, pregnant household member, one of more household members under 5y, household size, crop harvest in the past 12mo, household income, rural status, and region. These determinants explained 34% of the variance in the 'FAFH' pattern score.

Since the 'Traditional' food expenditure pattern was the only one to include fish and seafood, we also assessed associations between household fish and seafood expenditure and the potential social, economic, or environmental determinants as part of this exploratory analysis. In a binary logit model, any household food expenditure on fish and seafood was associated in the same direction as many of the same variables as the 'Traditional' pattern, including older head of household age and female sex, pregnant female household member, one or more household members under 5y, and higher monthly household income. In a separate multivariate regression model among only households with food expenditure on fish and seafood, we found consistent associations between total amount of fish and seafood expenditure with older head of household age and female sex, having one or more children under 5y, and higher monthly household income. Region and harvesting crops in the past 12mo were associated in all three models, but in varied directions.

3.3.5 Sensitivity analysis

In the first stage of the sensitivity analysis, we disaggregated the fish and seafood group into marine fish, freshwater fish, shellfish, and other fish and seafood. The three food expenditure patterns that we extracted (presented in Table 3.5) were similar to those from the main analysis and explained 22.7% of the total variance in food expenditure. The first pattern, which explained 8.5% of the total variance in food expenditure, resembled the 'Traditional' pattern from the main analysis by exhibiting strong positive correlations with household expenditure on vitamin A-rich fruit, dark green leafy vegetables, other vegetables, and white roots and plantains. The only type of fish and seafood that was strongly positively correlated was freshwater fish, though marine fish and shellfish approached the inclusion threshold, as well as red meat and vitamin A-rich fruit. The two other extracted patterns resembled the 'Processed foods' and 'Food away from home' patterns from the main analysis, and neither pattern included a fish and seafood group. The 'Processed foods' pattern explained 8.3% of the total variance in food expenditure and the 'FAFH' pattern explained 6.0%.

In the second stage of the sensitivity analysis, we further disaggregated the fish and seafood food group into species/genera. Similar to the first stage, we extracted three patterns (presented in Table 3.6) that explained 17.5% of the total variance in food expenditure. However, the first pattern we extracted resembled the 'Processed foods' pattern from the main analysis, which was strongly positively correlated with processed grain products, milk, sweets, and coffee, tea, and cocoa drinks. While no fish and seafood species/genera passed the inclusion threshold of 0.30, we noted that two marine species/genera, sardines and anchovy, had factor loadings above 0.20. The second pattern we extracted resembled the 'Traditional' pattern from the main analysis, but it was largely driven by strong positive correlations with two types of freshwater species/genera, tilapia and other freshwater fish, as well as white roots, plantains, and tubers. The third extracted pattern was similar to the 'FAFH' pattern from the main analysis. These three patterns explained 7.2%, 5.9%, and 4.4% of the total variance in food expenditure, respectively.

As with the main analysis, we explored associations between adherence to each food expenditure pattern and potential social, economic, or environmental determinants (Table 3.7 and Table 3.8). Nearly all the associations from the main analysis were statistically significant in the same direction as the analogous relationships in the sensitivity analysis. For example, head of household age and female sex was positively associated with adherence to the 'Traditional' expenditure pattern in both the main analysis and stages 1 and 2 of the sensitivity analysis. In contrast, household size and crop harvest in the past 12mo were always negatively associated with adherence to the 'Processed foods' and 'FAFH' patterns.

3.4 Discussion

Previous research finds differences in how fish and seafood contributes to Ghanaian diets among subpopulations defined by gender, life stage, and region (14–16,19–21,23). To qualify and compare these differences, we analyzed the food expenditures of a recent, nationally representative sample of Ghanaian households. Our analysis revealed three dominant food expenditure patterns: a 'Traditional' pattern, a 'Processed foods' pattern, and a 'Food away from home' pattern. We found that fish and seafood exhibits the highest factor loading of all animal source food groups in the ‘Traditional’ pattern, which included fruits, vegetables, white roots and tubers, and plantains. The ‘Processed foods’ pattern comprised processed cereal and grain products, milk, sugary snacks, coffee, tea, and cocoa drinks, eggs, and processed meat. Finally, the ‘Food away from home’ pattern comprised dishes prepared in restaurants and canteens, packaged water, and alcoholic beverages. The ‘Traditional’ and ‘Processed foods’ food expenditure patterns generally match the diet patterns identified by previous research conducted in Ghana (14–16,19–21,23); however, some notable differences emerged. Other studies found red meat (14,16,21,41), poultry (14,20,21), and sodas and juices (14,16,20,41) correlated with dairy products, sugary snacks, processed meat, and coffee and tea, which is similar to our ‘Processed foods’ pattern. However, our study found red meat moderately correlated in the ‘Traditional’ pattern and poultry and sodas and juices uncorrelated in any pattern.

One framework that contextualizes this research is the nutrition transition, which Popkin (1993) described as five succeeding nutrition patterns that are associated with distinct diets and types of malnutrition (13). The first three nutrition patterns, called ‘Collecting food’, ‘Famine’, and ‘Receding famine’ in that order, represent subsistence contexts or agricultural economies that feature diets heavily reliant on starchy staples and cereals. Some fruits, vegetables, and animal source foods are incorporated in the third ‘Receding famine’ pattern. The types of malnutrition prevalent in these patterns are undernourishment and micronutrient deficiencies, especially among infants, children, and reproductive age females. The fourth nutrition pattern, called ‘Degenerative diseases’, is composed of processed foods that are high in fat, sugar, and refined carbohydrates that are associated with increased risk of obesity. Reducing this increased risk of obesity drives the fifth and final nutrition pattern, called ‘Behavioral change’, as populations substitute processed foods in their diets for fruits and vegetables.

A large and diverse body of literature has documented the nutrition transition in Sub-Saharan Africa (45,46), the Middle East and North Africa (47–49), South Asia (50–52), and Latin America (53,54). Our study confirms that, a national level, Ghana's nutrition transition is in the third 'Receding famine' and fourth 'Degenerative diseases' patterns. The 'Traditional' food expenditure pattern closely maps to the third 'Receding famine' pattern as both are comprised of fruits, vegetables, and starchy staples with an animal source food, here fish and seafood . These foods are hallmarks of traditional Ghanaian cuisine where smoked marine fish and vegetables are boiled in soups and stews and served with pounded fermented cassava (55). Our 'Processed foods' and 'Food away from home' patterns, which include food groups composed of refined carbohydrates and added sugars, map closely to the fourth 'Degenerative diseases' pattern. However, our patterns provide additional information on where correlated food groups are purchased and prepared. The 'Processed foods' pattern comprises food products that appear to be purchased as ingredients and prepared in the home, while the 'FAFH' pattern includes mixed dishes, such as jolof rice and fried fish, that are prepared in restaurants and canteens. To our knowledge, previous research on diet patterns in Ghana has not analyzed data on whether food is prepared inside or outside the home (14–16,19–21,23), thus, the distinct 'Processed foods' and 'FAFH' patterns from this study are novel contributions to this literature. While Galbete et al. (2017) and Abubakari & Jahn (2016) included mixed dishes in their studies of diet patterns associated with urban and rural Ghanaian adults (15,16), they did not indicate where the mixed dishes were prepared and their results conflict with respect to which nutrition transition phase they were correlated.

In the second phase of our analysis, we considered several hypothesized determinants of adherence to the 'Traditional', 'Processed foods', and 'FAFH' food expenditure patterns. Popkin

(1993) proposed that household age structure, income disparities, occupations and roles, and rurality change alongside progression of the nutrition transition (13). These factors represent different conceptual dimensions of socioeconomic status across ecological levels (56). For our study, we decomposed these factors and expanded upon them to test a range of socioeconomic variables that fit into three determinant groups: sociodemographic factors (e.g., household ethnicity, religion, and composition), economic factors (e.g., household income, education, and type of food production), and environmental factors (e.g., region, rurality, and agroecology). Taken together, these results support that in Ghana's context, the 'Traditional' food expenditure pattern is associated with low socioeconomic status, the 'Processed foods' pattern with a blend of low and high socioeconomic variables, and the 'FAFH' pattern with high socioeconomic status.

3.4.1 Sociodemographic determinants

We tested for associations between several household-level sociodemographic characteristics and adherence to the three identified food expenditure patterns. Head of household age was positively associated with adherence to the 'Traditional' pattern but negatively associated with the 'Processed foods' and 'FAFH' patterns, which might be explained by the role of food choice in maintaining identity in adulthood. In a systematic review, Plastow et al. (2014) found that cooking traditional foods helped older populations preserve ethnic identity, especially when threatened by generational or societal change (57). This trend might manifest as older heads of households in Ghana exhibiting preferences for traditional dishes composed of foods from the 'Traditional' pattern amidst higher market penetration of processed foods, such as pasta and biscuits (58).

In seminal work, Rogers (1996) found no difference in how much female- or male-headed households in the Dominican Republic spent overall on food, but that female-headed households spent more on meat, poultry, and fish (59). In our study, we found that female-headed households were positively associated with adherence to the 'Traditional' and 'Processed foods' patterns, but negatively associated with the 'FAFH' pattern. As all three patterns identified in this study include animal source foods, our findings suggest that female heads exhibit the strongest preference for the mostly unprocessed foods of the 'Traditional' pattern, then processed foods, and the weakest preference for mixed dishes prepared by outside vendors. One reason why households with a pregnant female or one or more children preferred the 'Traditional' pattern might be food taboos or preferences during pregnancy and child rearing. Chakona & Shackleton (2019) describe examples of women abstaining from meat, fish and seafood , or fruits and vegetables across Africa (60–64) while in Ghana, Abubakari & Jahn (2016) found a positive association between avoiding meat but not fish and seafood and pregnancy status. A diet pattern rich in fruits, vegetables, and legumes among urban reproductive age females in the Northern Region (15). In contrast, Arzoaquoi et al. (2015) noted that pregnant women from the Kassena and Nankana ethnic groups located in the Upper East Region of Ghana are restricted to a vegetarian diet as they believe meat could lead to the birth of children who are possessed by spirits (65).

3.4.2 Economic determinants

We hypothesized that household food production might influence food expenditure by own food consumption or providing direct access to other food production that bypasses market distribution. In Asia, several studies support the positive role that fisheries participation plays in nutrition by bolstering household income and improving diet quality, often directly through fish and seafood consumption (66–69). In Africa, some research has found positive relationships between livestock ownership and diet quality (38,70–72), though other research yielded null or opposing findings (73,74). Our results found no association between household fisheries participation and livestock ownership in the past 12mo with adherence to any of the food expenditure patterns. In contrast, households harvesting crops in the past 12mo yielded negative associations with all three food expenditure patterns, possibly due to own consumption of agricultural goods influencing household food expenditure (75). For example, in Malawi, Jones (2017) found that household production of legumes, fruits and vegetables, and eggs was associated with increased diet diversity, often by consuming the produced food itself, and an inverse trend between production diversity and food expenditure (76).

Head of household secondary education was negatively associated with the ‘Traditional’ pattern but positively associated with the ‘Processed foods’ pattern. One explanation could be that secondary education enables household members to work outside the home, which might constrain time for cooking and increase reliance on processed foods that are more convenient to prepare (77). However, the importance of increased convenience might not extend to mixed dishes that are prepared outside the home, as the ‘FAFH’ food expenditure pattern was not associated with any of the food expenditure patterns.

Finally, monthly household income was positively associated with adherence to all three food expenditure patterns, though previous research has found inconsistent relationships. In Mozambique, Smart et al. (2020) found that household income was positively associated with expenditure on food items that we included in our ‘Processed foods’ pattern (beverages, eggs, and milk) and negatively associated with foods in our ‘Traditional’ pattern (vegetables, fruit, fish and seafood , nuts seeds and legumes, and roots and tubers) (78). At the regional level in East and Southern Africa, Tschirley et al. (2015) found a small positive association between household income and processed food expenditure but noted that processed foods represented the majority of total food spending across income levels (79).

3.4.3 Environmental determinants

Lastly, we explored environmental determinants and their relationships with the food expenditure patterns. Rural status was positively associated with adherence to the 'Traditional' pattern but negatively associated with the 'FAFH' pattern, which mirror food expenditure trends in Eastern and Southern Africa (79,80). These associations might be influenced by characteristics of rural food environments, where households might rely more on informal markets that distribute locally grown fruits, vegetables, and starchy staples, thus increasing adherence to the 'Traditional' food expenditure pattern. On the other hand, higher density and closer proximity of food vendors in urban environments increases access and availability of food away from home (81). Household region of residence was overall associated with adherence to all three patterns, but only a few specific regions yielded statistically significant associations in either direction when compared to Greater Accra. Finally, yearly quarter or survey timing, which describes seasonality or special events, such as holidays (26), was not associated with adherence to any food expenditure pattern. These null associations could be year-round availability of foods that dominate each expenditure pattern. While plausible for the 'Processed foods' and 'FAFH' patterns, the 'Traditional' pattern largely comprises fruits and vegetables that are highly perishable and strongly affected by seasonality (82).

3.4.4 Comparing determinants of the 'Traditional' pattern and food expenditure on fish and seafood

Most sociodemographic, economic, and environmental factors were associated with the 'Traditional' food expenditure pattern and food expenditure on fish and seafood in the same direction, but there were a few notable exceptions. Household crop harvest in the past 12 months was negatively associated with the 'Traditional' pattern but positively associated with fish and seafood expenditure. The opposing relationships for household crop harvest in the past 12mo might be due to own consumption of starchy staples, fruits, and vegetables (75), but needing to purchase fish and seafood as a source of animal protein. Previous research supports the influence of household religion (28) and pregnancy status (15) on household fish and seafood consumption expenditure, which might be driven by ethnic or religious food taboos and preferences. For example, Seventh Day Adventists do not consume scaleless fish and seafood or crawling animals, such as catfish and crab, respectively (83). Qualitative research found that women living in Accra increased shellfish consumption to increase calcium intake during pregnancy at the recommendations of healthcare professionals (27). While these factors might determine food expenditure when studying subpopulations, we found null associations at the national level.

Other factors were associated with fish and seafood expenditure but not with adherence to the 'Traditional' food expenditure pattern. Ga-Dangme and Ewe ethnicities were both positively associated with fish and seafood expenditure, which could be explained by their historical ties to marine fishing (84). Household size was negatively associated with food expenditure on fish and seafood , which aligns with Deaton & Paxson (1998)'s landmark study of household scale economies that described an inverse relationship between household size and per capita demand for food across the United States, Europe, Africa, and Asia (85). Finally, households that reported food expenditure from October to December (Quarter 4) were negatively associated with food expenditure on fish and seafood when compared to households in January through March (Quarter 1). This could be explained by relatively low demand for fish and seafood during the fisheries lean season that occurs during Quarter 4 in comparison to the minor fisheries bumper season during the referent, Quarter 1 (86). However, Onumah et al. (2020) observed the opposite in a longitudinal study of households in two urban centers, Accra and Tamale (28). The authors noted that households in these locales might be more able to absorb higher prices for a dwindling but still present supply of fish and seafood . In rural regions, the supply of fish and seafood might be more tenuous (44) and households might forego food expenditure on fish and seafood and substitute other types of foods.

3.4.5 Sensitivity analysis

We learned two lessons by conducting our sensitivity analysis, which assessed how disaggregating one fish and seafood group into more biodiversity-informed fish and seafood groups influenced food expenditure patterns and their associations with potential socioeconomic determinants.

The first lesson was that heterogeneity in fish and seafood consumption is relevant to patterns of food-related behaviors that map to Ghana's nutrition transition. Both stages of the sensitivity analysis produced similar food expenditure patterns as the main analysis: the 'Traditional' patterns was analogous to the 'Receding famine' pattern and the 'Processed foods' and 'FAFH' patterns to the 'Degenerative diseases' pattern. However, the second stage of the sensitivity analysis revealed that the 'Traditional' pattern was strongly positively correlated with tilapia and other freshwater fish, while the 'Processed foods' pattern was moderately correlated with sardines and anchovy. These distinctions provide important information for nutrition monitoring. For example, oily marine fishes like sardines and anchovy contain higher levels of polyunsaturated fatty acids, calcium, iron, and zinc than tilapia, especially when consumed whole (25). The absence of sardines and anchovy in households that adhered to the 'Traditional' pattern is particularly noteworthy; adherence to this pattern was associated with household pregnancy and children aged under 5y, two life stages in which these nutrients are particularly valuable for health growth and development.

The second lesson is that disaggregating food groups can reveal important biodiversity and food systems information. All fish and seafood species/genera were aggregated into one fish and seafood group in the main analysis, which obscured nuances in ecosystem and production source and their implications for nutrition. These nuances were observable in the second stage of the sensitivity analysis, which found marine and freshwater species/genera in different food expenditure pattern. Furthermore, the second stage distinguished freshwater species/genera by production source, as recent national policies promote intensified aquaculture in Lake Volta, as well as protected domestic tilapia consumption using an import ban (87–89). On the other hand, marine species/genera could be sourced by wild capture, thus potentially impacted by seasonal fisheries closures designed to slow the decline of forage fish stocks (90–92).

3.5 Strengths, Limitations, & Policy Implications

The most prominent strength of this study is the use of household data as part of the seventh round of the Ghana Living Standards Survey, a version of the Living Standards Measurement Study that was developed by the Policy Research Division of The World Bank. Most previous research that typifies food-related behavior in Ghana relies on relatively smaller samples defined by one specific region, gender, or life stage, which diminishes the generalizability of their results. Our study analyzed food expenditure data from a large, nationally representative sample of households in Ghana, thus, our analysis describes trends in food-related behaviors with a high precision at the national level. The GLSS 7 also boasts a high response rate of 93.4% of selected households (33), a consistent feature of national surveys conducted in Africa (93,94). Due to the agricultural focus of the seventh round, the food list was highly disaggregated and incorporated biodiversity, food processing, and company brand information into the recall items. This detailed information allowed us to interpret the food expenditure patterns in the context of nutrition transition in the main analysis and to test whether the patterns were sensitive to disaggregating fish and seafood into biodiversity-informed groups. Finally, the GLSS 7 used standardized survey instruments to collect abundant household data over an entire month, so we could test for associations across a range of sociodemographic, economic, and environmental dimensions.

This study had several limitations. First, the observational cross-sectional design of our study did not allow for establishing causality between sociodemographic, economic, and environmental factors and adherence to the food expenditure patterns. A second limitation is our use of household food expenditure data in contrast to previous diet pattern research in Ghana that used individual-level dietary data. While this methodological mismatch limits direct comparisons of results, the food expenditure patterns we identified fit into the research discourse that supports the nutrition transition occurring in Ghana.

Our findings are relevant to several aspects of the food and nutrition sector. One practical application is that Ghana's national or local governments could use these results to develop food-based nutrition interventions. If seeking to incentivize fish and seafood, these interventions could subsidize the types important to nutrition transition patterns of specific subpopulations. This research also adds to an established discourse on using household food consumption expenditure data as a substitute for individual food consumption data when describing food-related behaviors (31). Finally, by including biodiversity principles into our sensitivity analysis, our research provides information that is interoperable for the fisheries, food, and nutrition sectors. As wild capture fisheries are managed by setting catch limits for individual types of fish and seafood, and are differ from aquaculture enterprises by intensity of human input, we provide the fisheries sector with important information for estimating consumer demand.

3.6 Conclusion

Fish and seafood consumption is a potential food-based intervention for addressing the triple burden of malnutrition in countries reliant on fisheries for food. Our study in Ghana reveals three dominant patterns of household food expenditure that map to the 'Receding famine' and 'Degenerative diseases' patterns of the nutrition transition (13). Furthermore, we clarify that fish and seafood is the only animal source food in a pattern of household expenditure on fruits, vegetables, and starchy staples, but not in patterns that rely on processed foods or food away from home. While we found that the 'Traditional' pattern and the 'FAFH' pattern were associated with low and high socioeconomic status, respectively, the 'Processed foods' pattern could represent households in transition as it presented mixed associations depending on socioeconomic dimension. Head household age, sex, religion, and educational level, households with a pregnant female or children under 5y, and rurality were consistently associated with adherence to all three food expenditure patterns, underscoring their importance when identifying whether fish and seafood consumption or other food-based interventions might be appropriate for addressing one or more types of malnutrition occurring in a specific population. By disaggregating fish and seafood into species/genera, we show differences in how each are consumed by ecosystem or food production sources. A feasible next step for this line of research is to test individual socioeconomic determinants for interactions, such as female-headed household status and household income (76), rural status, or households harvesting crops (95).

Research using household-level consumption data would also be useful to see if the same fish and seafood-containing food behavior patterns emerge with the same relationships with socioeconomic status. With clearer and more detailed evidence on the role of fish and seafood in household food expenditure and diet patterns, the fisheries, food, and nutrition sectors can work together to design multisectoral policies and programs to alleviate the triple burden of malnutrition.

3.7 References

1. FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome: FAO; 2022.
2. Shahidi F, Ambigaipalan P. Omega-3 Polyunsaturated Fatty Acids and Their Health Benefits. Annual Review of Food Science and Technology. 2018;9:345–81.
3. Bene C, Arthur R, Norbury H, Allison EH, Beveridge M, Bush S, et al. Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence. World Development. 2016;79:177–96.
4. Bogard JR, Thilsted SH, Marks GC, Wahab MA, Hossain MAR, Jakobsen J, et al. Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. Journal of Food Composition and Analysis. 2015;42:120–33.
5. Hicks CC, Cohen PJ, Graham NAJ, Nash KL, Allison EH, D'Lima C, et al. Harnessing global fisheries to tackle micronutrient deficiencies. Nature. 2019;574(7776):95–8.
6. Kawarazuka N, Bene C. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutr. 2011;14(11):1927–38.
7. Bogard JR, Hother AL, Saha M, Bose S, Kabir H, Marks GC, et al. Inclusion of Small Indigenous Fish Improves Nutritional Quality During the First 1000 Days. Food Nutr Bull. 2015;36(3):276–89.
8. Byrd KA, Pincus L, Pasqualino MM, Muzofa F, Cole SM. Dried small fish provide nutrient densities important for the first 1000 days. Maternal and Child Nutrition. 2021;17(4):1–13.
9. Roos N, Wahab MA, Chamnan C, Thilsted SH. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. J Nutr. 2007;137(4):1106–9.

10. Roos N, Wahab MA, Hossain MA, Thilsted SH. Linking human nutrition and fisheries: incorporating micronutrient-dense, small indigenous fish species in carp polyculture production in Bangladesh. Food Nutr Bull. 2007;28(2 Suppl):S280-93.

11. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean diet and survival in a Greek population. N Engl J Med. 2003;348(26):2599–608.

12. Thilsted SH, Thorne-Lyman A, Webb P, Bogard JR, Subasinghe R, Phillips MJ, et al. Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. Food Policy. 2016;61:126–31.

13. Popkin BM. Nutritional Patterns and Transitions. Population and Development Review. 1993;19(1):138–57.

14. Abizari AR, Ali Z. Dietary patterns and associated factors of schooling Ghanaian adolescents. J Health Popul Nutr. 2019;38(1):5.

15. Abubakari A, Jahn A. Maternal Dietary Patterns and Practices and Birth Weight in Northern Ghana. PLoS One. 2016;11(9):e0162285.

16. Galbete C, Nicolaou M, Meeks KA, de-Graft Aikins A, Addo J, Amoah SK, et al. Food consumption, nutrient intake, and dietary patterns in Ghanaian migrants in Europe and their compatriots in Ghana. Food Nutr Res. 2017;61(1):1341809.

17. Galbete C, Nicolaou M, Meeks K, Klipstein-Grobusch K, de-Graft Aikins A, Addo J, et al. Dietary patterns and type 2 diabetes among Ghanaian migrants in Europe and their compatriots in Ghana: the RODAM study. Nutr Diabetes. 2018;8(1):25.

18. Frank LK, Jannasch F, Kroger J, Bedu-Addo G, Mockenhaupt FP, Schulze MB, et al. A Dietary Pattern Derived by Reduced Rank Regression is Associated with Type 2 Diabetes in An Urban Ghanaian Population. Nutrients. 2015;7(7):5497–514.

19. Kubuga CK, Kennedy G, Song WO. Food-based indicators are related to iron and iodine deficiencies of mother-toddler dyads during the lean season in northern Ghana. Br J Nutr. 2020;1–10.

20. Ogum Alangea D, Aryeetey RN, Gray HL, Laar AK, Adanu RMK. Dietary patterns and associated risk factors among school age children in urban Ghana. BMC Nutr. 2018;4:22.

21. Quansah DY, Boateng D. Maternal dietary diversity and pattern during pregnancy is associated with low infant birth weight in the Cape Coast metropolitan hospital, Ghana: A hospital based cross-sectional study. Heliyon. 2020;6(5):e03923.

22. Mockshell J, Asante-Addo C, Andam KS, Asante F. Transitioning to nutrition-sensitive food environments in Ghana: Triple sector strategies to reduce the triple burden of malnutrition. 2021;52.

23. Jannasch F, Bedu-Addo G, Schulze MB, Mockenhaupt FP, Danquah I. Serum phospholipid fatty acids, dietary patterns and type 2 diabetes among urban Ghanaians. Nutr J. 2017;16(1):63.

24. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana's evolving protein economy. Food Security. 2016;8(5):909–20.

25. Ministry of Food and Agriculture and University of Ghana School of Public Health. Food-Based Dietary Guidelines [Internet]. 2023. Available from: https://mofa.gov.gh/site/images/pdf/Ghana_Food_Based_Dietary_Guidelines_2023.pdf

26. Akuffo A S, Quagrainie KK, Obirikorang KA. Analysis of the determinants of fish consumption by households in Ghana. Aquaculture Economics & Management. 2020;24(3).

27. Gersten Z, Akrofi MNA, Sarpong DB, Jones A. 'What I Know Is that I Like Fish': A Qualitative Study of Food System Factors Influencing Fish Consumption Among Women in Accra, Ghana. Current Developments in Nutrition. 2020;4(Supplement_2):832.

28. Onumah EE, Quaye EA, Ahwireng AK, Campion BB. Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. Sustainability. 2020;12(19):7932.

29. Dey MM, Garcia YT, Praduman K, Piumsombun S, Haque MS, Li L, et al. Demand for fish in Asia: a cross-country analysis*. Australian Journal of Agricultural and Resource Economics. 2008;52(3):321–38.

30. Vincent A, Grande F, Compaoré E, Amponsah Annor G, Addy PA, Aburime LC, et al. FAO/INFOODS Food Composition Table for Western Africa (2019) User Guide & Condensed Food Composition Table / Table de composition des aliments FAO/INFOODS pour l'Afrique de l'Ouest (2019) Guide d'utilisation & table de composition des aliments condensée. Rome: Food and Agriculture Organization of the United Nations; 2020.

31. Tang K, Adams KP, Ferguson EL, Woldt M, Yourkavitch J, Pedersen S, et al. Systematic review of metrics used to characterize dietary nutrient supply from household consumption and expenditure surveys. Public Health Nutrition. 2022;25(5):1153–65.

32. Weisell R, Dop MC. The adult male equivalent concept and its application to Household Consumption and Expenditures Surveys (HCES). Food and nutrition bulletin. 2012;33(3 Suppl):157–62.

33. Ghana Statistical Service. Ghana Living Standards Survey round 7 (GLSS7), Main Report [Internet]. Ghana Statistical Service. Accra: Ghana Statistical Service; 2019 p. 1–343. Available from: https://statsghana.gov.gh/gsspublications.php?category=MTAwMjg3Mzk3NC4zMDc=/webstats/1opr93rn57

34. Ghana Statistical Service. Ghana Living Standards Survey (GLSS7): Poverty trends in Ghana; 2005-2017. Ghana Statistical Service. 2018;14–21.

35. Martin-Prevel Y, Arimond M, Allemand P, Wiesmann D, Ballard TJ, Deitchler M, et al. Development of a Dichotomous Indicator for Population-Level Assessment of Dietary Diversity in Women of Reproductive Age. Current Developments in Nutrition. 2017;1(12).

36. Ghana Statistical Service. Ghana Living Standards Survey round 6 (GLSS6), Main Report. Accra: Ghana Statistical Service; 2014.

37. Deaton A, Grosh M. Designing Household Survey Questionnaires for Developing Countries Lessons from Ten Years of LSMS Experience, Chapter 17: Consumption [Internet]. Princeton University, Woodrow Wilson School of Public and International Affairs, Research Program in Development Studies; (Working Papers). Report No.: 218. Available from: https://ideas.repec.org/p/pri/rpdevs/deaton_grosh_consumption.pdf.html

38. Azzarri C, Zezza A, Haile B, Cross E. Does Livestock Ownership Affect Animal Source Foods Consumption and Child Nutritional Status? Evidence from Rural Uganda. The Journal of Development Studies. 2015;51(8):1034–59.

39. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol. 2002;13(1):3–9.

40. Michels KB, Schulze MB. Can dietary patterns help us detect diet-disease associations? Nutr Res Rev. 2005;18(2):241–8.

41. Frank LK, Kroger J, Schulze MB, Bedu-Addo G, Mockenhaupt FP, Danquah I. Dietary patterns in urban Ghana and risk of type 2 diabetes. Br J Nutr. 2014;112(1):89–98.

42. Abdi H, Williams LJ. Principal component analysis. Wiley Interdisciplinary Reviews: Computational Statistics. 2010;2(4):433–59.

43. Redford KH, Richter BD. Conservation of Biodiversity in a World of Use. Conservation Biology. 1999;13(6):1246–56.

44. Tiwaah Amoah Y, Hardi B, Beran K, The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Understanding the flow of fish: A scoping visit to Northern Ghana. Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and MOFAD,; 2015 p. 25.

45. Steyn NP, Mchiza ZJ. Obesity and the nutrition transition in Sub-Saharan Africa. Annals of the New York Academy of Sciences. 2014;1311(1):88–101.

46. Rousham EK, Pradeilles R, Akparibo R, Aryeetey R, Bash K, Booth A, et al. Dietary behaviours in the context of nutrition transition: a systematic review and meta-analyses in two African countries. Public Health Nutr. 2020 Aug;23(11):1948–64.

47. Zaghloul S, Al-Hooti SN, Al-Hamad N, Al-Zenki S, Alomirah H, Alayan I, et al. Evidence for nutrition transition in Kuwait: over-consumption of macronutrients and obesity. Public Health Nutr. 2013 Apr;16(4):596–607.

48. Belfki H, Ali SB, Aounallah-Skhiri H, Traissac P, Bougatef S, Maire B, et al. Prevalence and determinants of the metabolic syndrome among Tunisian adults: results of the Transition and Health Impact in North Africa (TAHINA) project. Public Health Nutr. 2013 Apr;16(4):582–90.

49. Madanat HN, Lindsay R, Campbell T. Young urban women and the nutrition transition in Jordan. Public Health Nutr. 2011 Apr;14(4):599–604.

50. Shetty PS. Nutrition transition in India. Public Health Nutr. 2002 Feb;5(1a):175–82.

51. Yagya Prasad Subedi, Debbi Marais, David Newlands. Where is Nepal in the nutrition transition? Asia Pacific Journal of Clinical Nutrition. 2017 Mar 1;26(2).

52. Griffiths PL, Bentley ME. The Nutrition Transition Is Underway in India. The Journal of Nutrition. 2001 Oct;131(10):2692–700.

53. Albala C, Vio F, Kain J, Uauy R. Nutrition transition in Chile: determinants and consequences. Public Health Nutr. 2002 Feb;5(1a):123–8.

54. Rivera JA, Barquera S, González-Cossío T, Olaiz G, Sepúlveda J. Nutrition Transition in Mexico and in Other Latin American Countries. Nutrition Reviews. 2004 Jul;62:S149–57.

55. Nti CA. Household dietary practices and family nutritional status in rural Ghana. Nutr Res Pract. 2008;2(1):35–40.

56. Fotso JC, Kuate-Defo B. Measuring socioeconomic status in health research in developing countries: Should we be focusing on households, communities or both? Social Indicators Research. 2005;72:189–237.

57. Plastow NA, Atwal A, Gilhooly M. Food activities and identity maintenance in old age: A systematic review and meta-synthesis. Aging and Mental Health. 2015;19(8):667–78.

58. Andam K, Silver J. Food Processing in Ghana: Trends, Constraints, and Opportunities. Ghana Strategy Support Program, International Food Policy Research Institute, Policy Note 11. 2016;2013(October):2013–6.

59. Rogers BL. The implications of female household headship for food consumption and nutritional status in the Dominican Republic. World Development. 1996;24(1):113–28.

60. Chakona G, Shackleton C. Food Taboos and Cultural Beliefs Influence Food Choice and Dietary Preferences among Pregnant Women in the Eastern Cape, South Africa. Nutrients. 5(11):1668.

61. Martínez Pérez G, Pascual García A. Nutritional Taboos among the Fullas in Upper River Region, The Gambia. Journal of Anthropology. 2013;2013:1–9.

62. Ekwochi U, Osuorah CDI, Ndu IK, Ifediora C, Asinobi IN, Eke CB. Food taboos and myths in South Eastern Nigeria: The belief and practice of mothers in the region. Journal of Ethnobiology and Ethnomedicine. 2016;12(1):1–6.

63. Zepro NB. Food taboos and misconceptions among pregnant women of Shashemene District, Ethiopia, 2012. Science Journal of Public health. 2015;3(3):410–6.

64. Vasilevski V, Carolan-Olah M. Food taboos and nutrition-related pregnancy concerns among Ethiopian women. Journal of Clinical Nursing. 2016;25(19–20):3069–75.

65. Arzoaquoi SK, Essuman EE, Gbagbo FY, Tenkorang EY, Soyiri I, Laar AK. Motivations for food prohibitions during pregnancy and their enforcement mechanisms in a rural Ghanaian district. Journal of Ethnobiology and Ethnomedicine. 2015;11(1):1–9.

66. Ahmed BN, Waibel H. The role of homestead fish ponds for household nutrition security in Bangladesh. Food Security. 2019;11:835–54.

67. Akter R, Thilsted SH, Hossain N, Ishihara H, Yagi N. Fish is the Preferred Animal-Source Food in the Rural Community of Southern Bangladesh. Sustainability. 2019;11(20):6764.

68. Bernzen A, Mangnus E, Sohns F. Diversify, produce or buy? An analysis of factors contributing to household dietary diversity among shrimp and non-shrimp farmers in coastal Bangladesh. Food Security. 2022;14(741–761).

69. Aung YM, Khor LY, Tran N, Akester M, Zeller M. The impact of sustainable aquaculture technologies on the welfare of small-scale fish farming households in Myanmar. Aquaculture Economics & Management. 2021;Ahead-of-print:1–30.

70. Ayele Z, Peacock, Christie. Improving access to and consumption of animal source foods in rural households: the experiences of a women-focused goat development program in the highlands of Ethiopia. The Journal of nutrition. 2003;133(11 Suppl 2):3981S-3986S.

71. Jin M, Ianotti LL. Livestock production, animal source food intake, and young child growth: the role of gender for ensuring nutrition impacts. Social Science & Medicine. 2014;105:16–21.

72. Rawlins R, Pimkina S, Barrett CB, Pedersen S, Wydick B. Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. Food Policy. 2014;44:202–13.

73. Dumas SE, Kassa L, Young SL, Travis AJ. Examining the association between livestock ownership typologies and child nutrition in the Luangwa Valley, Zambia. PLoS One. 2018;13(2):e0191339.

74. Hetherington JB, Wiethoelter AK, Negin J, Mor S M. Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. Agriculture & Food Security. 2017;6(9).

75. Singh I, Squire L, Strauss J, World Bank. Agricultural household models : extensions, applications, and policy. 1986;335.

76. Jones AD, Shrinivas A, Bezner-Kerr R. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. Food Policy. 2014;46:1–12.

77. Reardon T, Tschirley D, Liverpool-Tasie LSO, Awokuse T, Fanzo J, Minten B, et al. The processed food revolution in African food systems and the double burden of malnutrition. Global Food Security. 2021;28:100466.

78. Smart JC, Tschirley D, Smart F. Diet Quality and Urbanization in Mozambique. Food and Nutrition Bulletin. 2020;41(3):298–317.

79. Tschirley D, Reardon T, Dolislager M. The Rise of a Middle Class in East and Southern Africa: Implications for Food System Transformation.

80. Sauer CM, Reardon T, Tschirley D, Liverpool-Tasie S, Awokuse T, Alphonce R, et al. Consumption of processed food & food away from home in big cities, small towns, and rural areas of Tanzania. Agricultural Economics (United Kingdom). 2021;52(5):749–70.

81. Bren d'Amour C, Pandey B, Reba M, Ahmad S, Creutzig F, Seto KC. Urbanization, processed foods, and eating out in India. Global Food Security. 2020;25(February).

82. Bai Y, Naumova EN, Masters WA. Seasonality of diet costs reveals food system performance in East Africa. Science Advances. 2020;6(49):1–11.

83. Gadegbeku C. Food taboos among residents at Ashongman - Accra, Ghana. Food Science and Quality Management. 2013;15.

84. Akyeampong E. Indigenous Knowledge and Maritime Fishing in West Africa: the Case of Ghana. In: Boon E, Hens L, editors. Indigenous Knowledge Systems and Sustainable Development: Relevance for Africa. Delhi: Kamla-Raj Enterprises; 2007.

85. Deaton A, Paxson C. Economies of Scale, Household Size, and the Demand for Food. Journal of Political Economy. 1998;106(5):897–930.

86. Hasselberg AE, Aakre I, Scholtens J, Overå R, Kolding J, Bank MS, et al. Fish for food and nutrition security in Ghana: Challenges and opportunities. Global Food Security. 2020;26:100380.

87. Ministry of Food and Agriculture, Fisheries Commission. Ghana National Aquaculture Development Plan (GNADP) [Internet]. Accra, Ghana: Ministry of Food and Agriculture; 2012. Available from: https://faolex.fao.org/docs/pdf/gha149443.pdf

88. Ragasa C, Andam KS, Asante SB, Amewu S. Can local products compete against imports in West Africa? Supply- and demand-side perspectives on chicken, rice, and tilapia in Ghana. Global Food Security. 2020;26.

89. Ragasa C, Agyakwah SK, Asmah R, Mensah ETD, Amewu S, Oyih M. Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana. Aquaculture. 2022 Jan;547:737476.

90. Apetorgbor S. Closed Season Brief. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018 p. 10. Report No.: GH2014_POL109_CRC.

91. Lazar N, Yankson K, Blay J, Ofori-Danson P, Markwei P, Agbogah K, et al. Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018. Report No.: GH2014_SCI042_CRC.

92. Owusu V, Andriesse E. From open access regime to closed fishing season: Lessons from small-scale coastal fisheries in the Western Region of Ghana. Marine Policy. 2020;(August):104162.

93. Meyer BD, Mok WKC, Sullivan JX. Household surveys in crisis. Journal of Economic Perspectives. 2015;29(4):199–226.

94. Mishra V, Barrere B, Hong R, Khan S. Evaluation of bias in HIV seroprevalence estimates from national household surveys. Sexually Transmitted Infections. 2008;84(SUPPL. 1):63–70.

95. Mafuru JM, Marsh TL. An Analysis Of Household Food Expenditure Systems In Tanzania. In Denver, Colorado: Western Agricultural Economics Association; 2003.

3.8 Tables and figures

Table 3.1: Sociodemographic, economic, and environmental characteristics of the GLSS 7 sample.

	All	Male-headed household	Female-headed household	Urban households	Rural households
Head of household age (years)	45.1 (0.2)	43.6 (0.2)	47.9 (0.4)	44.2 (0.3)	46.2 (0.3)
Female-headed household (%)	35.1	---	---	37.1	32.4
Head of household religion (%)					
Christian	79.7	75.5	87.4	80.7	78.4
Muslim	16.5	19.9	10.2	18.6	13.7
Traditionalist	3.8	4.6	2.3	0.7	7.9
Head of household ethnicity (%)					
Akan	52.5	49.2	58.6	54.7	49.7
Ga-Dangme	8.0	7.7	8.6	9.8	5.7
Ewe	12.8	12.2	14.0	12.5	13.3
Guan	3.6	3.6	3.5	3.3	4.0
Gurma	4.3	5.0	3.0	2.7	6.4
Mole-Dagbani	13.9	16.6	9.1	12.3	16.1
Grusi	2.5	2.8	1.8	2.1	2.9
Mande	1.0	1.1	0.8	0.9	1.1
Other ethnic groups	1.4	1.8	0.6	1.8	0.9
Household pregnancy (%)	4.6	5.5	2.9	4.1	5.3
Children in household under 5y (%)	35.2	39.0	28.2	30.7	41.0
Number of adult equivalents	2.9 (0.0)	3.2 (0.0)	2.4 (0.0)	2.7 (0.0)	3.2 (0.0)
Head of household secondary education or higher (%)	27.1	32.5	17.2	36.1	15.4
Fishing, fish farming, or fish processing	2.1	2.1	2.2	2.1	2.1
Livestock ownership	19.4	23.2	12.4	8.2	34.0
Harvested crops	22.7	25.0	18.5	8.6	41.1
Monthly household income per AME (cedis)	334.4 (0.0)	323.1 (1.0)	351.4 (1.0)	442.7 (1.0)	231.8 (1.0)
Rural status	43.4	45.1	40.1	---	---
Region (%)					
Greater Accra	18.4	18.6	18.1	29.5	3.8
Western	10.0	10.8	8.6	8.2	12.4
Central	8.4	7.6	9.9	7.0	10.3
Volta	7.3	6.8	8.3	4.8	10.6
Eastern	11.8	11.5	12.3	10.0	14.1
Ashanti	22.8	20.9	26.4	25.6	19.2
Brong Ahafo	9.1	8.9	9.3	7.9	10.7
Northern	6.7	8.8	2.8	4.9	8.9
Upper East	3.2	3.5	2.7	1.3	5.7
Upper West	2.3	2.7	1.6	0.8	4.2
Agroecological zone					
Accra Metropolitan Assembly	7.1	6.9	7.3	12.5	---
Coastal	24.3	23.2	26.4	29.1	18.1
Forest	51.2	49.3	54.6	47.7	55.7
Savannah	17.5	20.5	11.8	10.7	26.2
Survey quarter					
January-March	30.3	30.5	30.0	26.9	34.7
April-June	20.5	20.9	19.7	20.2	20.8
July-September	29.9	29.6	30.3	32.4	26.6
October-December	19.4	19.0	20.1	20.5	17.9

Data are shown as mean (standard error) unless otherwise stated.

Table 3.2: Factor loadings of food groups for three food expenditure patterns derived by principal component analysis in 12,738 households.

Food group	'Traditional'	'Processed Foods'	'Food away from home'
Rice	0.03	0.08	-0.07
Other grains	-0.13	-0.08	0.05
Maize	-0.01	0.00	-0.01
Processed grain products	0.09	0.36**	0.12
Baby food (Cerelac)	-0.02	0.10	0.00
Processed cassava	0.10	0.09	0.02
Fish and seafood	0.38**	0.03	-0.01
Red meat	0.22*	-0.10	-0.02
Poultry	0.11	-0.06	0.00
Processed meat	-0.06	0.24*	-0.04
Other meat	0.08	0.03	-0.01
Milk	-0.03	0.39**	0.00
Sweets	-0.13	0.44**	-0.08
Eggs	0.12	0.19	0.05
Oils and fats	0.11	0.12	-0.12
Vitamin A-rich fruit	0.32**	0.07	0.11
Other fruit	0.18	0.23*	0.26*
Dark green leafy vegetables	0.36**	-0.10	0.04
Vitamin A-rich vegetables	0.21*	-0.02	0.03
Other vegetables	0.37**	0.05	-0.05
Nuts, seeds, and pulses	-0.01	0.08	-0.12
White roots and plantains	0.46**	-0.07	0.00
Salt and spices	-0.08	0.05	-0.05
Coffee, tea, and cocoa drinks	-0.03	0.41**	0.03
Water	0.08	0.11	0.43**
Sodas and juices	-0.05	0.16	0.11
Malt beverages	-0.15	0.07	0.13
Alcoholic beverages	-0.10	-0.26*	0.56**
Food away from home	-0.08	0.05	0.56**

**Factor loading ≥ |0.3|
*Factor loading ≥ |0.2|

Table 3.3: Sociodemographic, economic, and environmental characteristics of GLSS 7 households across quintiles of expenditure patterns.

	'Traditional' pattern			**'Processed foods' pattern**			**'Food away from home' pattern**		
	Q1	**Q3**	**Q5**	**Q1**	**Q3**	**Q5**	**Q1**	**Q3**	**Q5**
Head of household age (years)	42.1 (19.2)	45.0 (14.0)	47.5 (14.4)	48.6 (18.3)	45.3 (14.3)	41.5 (14.1)	48.3 (19.1)	45.7 (13.9)	39.9 (12.9)
Female-headed household (%)	3.4	6.9	10.2	5.4	7.2	8.0	7.1†	7.6†	5.6†
Head of household religion (%)									
Christian	13.4	16.2	17.7	14.5	16.2	17.0	12.9	16.4	17.4
Muslim	4.8	3.3	2.0	3.2	3.5	2.9	5.4	3.0	2.4
Traditionalist	1.9	0.5	0.2	2.4	0.4	0.1	1.7	0.6	0.2
Head of household ethnicity (%)									
Akan	7.9	10.8	12.2	8.4	11.2	11.3	7.2	11.6	11.9
Ga-Dangme	1.0	1.6	2.2	0.9	1.5	2.5	0.8	1.5	2.6
Ewe	1.5	3.2	2.7	2.0	2.8	2.5	2.2	2.5	2.5
Guan	0.6	0.7	0.8	0.7	0.7	0.7	1.0	0.8	0.5
Gurma	1.8	0.7	0.2	2.0	0.6	0.3	1.5	0.8	0.3
Mole-Dagbani	5.5	2.1	1.4	4.7	2.3	2.0	5.7	2.1	1.6
Grusi	1.0	0.4	0.2	1.0	0.3	0.3	1.1	0.3	0.3
Mande	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.1
Other ethnic groups	0.4	0.3	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Household pregnancy (%)	0.8†	1.0†	0.8†	1.1†	1.0†	0.8†	1.2	0.9	0.4
Children in household under 5y (%)	6.6	8.1	4.2	8.4	7.5	4.3	10.0	8.1	1.7
Number of adult equivalents	3.1 (3.1)	3.1 (1.6)	2.0 (1.1)	3.9 (2.8)	3.0 (1.7)	1.8 (1.1)	3.9 (2.8)	3.2 (1.6)	1.4 (0.7)
Head of household secondary education (%)	5.0	5.1	7.4	2.3	5.3	9.7	2.4	5.2	9.3
Fishing, fish farming, or fish processing (%)	0.3†	0.6†	0.3†	0.4†	0.5†	0.4†	0.3	0.6	0.3
Livestock ownership (%)	5.8	4.0	1.6	7.3	3.5	1.1	7.8	3.4	1.0
Crops harvested (%)	5.2	5.4	2.0	8.0	4.4	1.2	8.5	4.1	1.1
Monthly household income per AME (cedis)	208.8 (3.5)	307.8 (1.6)	707.9 (1.6)	159.9 (2.7)	327.7 (1.6)	769.6 (1.6)	174.1 (2.8)	325.3 (1.7)	736.3 (1.6)
Rural status (%)	11.6	8.6	5.5	14.2	8.0	4.2	15.3	7.6	3.9
Region (%)									
Greater Accra	1.9	3.1	6.5	0.9	3.6	7.2	0.1	3.1	7.8
Western	1.6	2.3	1.4	1.9	2.4	1.5	1.6	2.4	1.2
Central	0.7	2.0	2.2	0.8	1.8	2.3	1.2	2.1	1.4
Volta	1.1	2.0	0.9	1.9	1.5	0.8	2.1	1.3	0.7
Eastern	1.3	2.6	2.7	2.1	2.5	2.1	2.1	3.0	1.8
Ashanti	4.6	5.0	4.4	3.9	4.9	4.2	3.3	5.2	5.4
Brong Ahafo	2.1	1.8	1.2	3.1	1.6	0.9	2.9	1.6	1.2
Northern	3.4	0.8	0.4	2.0	1.2	0.8	3.3	0.8	0.4
Upper East	1.8	0.4	0.1	2.1	0.3	0.2	2.0	0.2	0.1
Upper West	1.5	0.2	0.1	1.3	0.2	0.1	1.4	0.3	0.1
Agroecological zone (%)									
Accra Metropolitan Assembly	0.8	1.0	2.8	0.3	0.9	3.7	0.0	1.0	3.6
Coastal	2.4	5.3	6.7	2.0	5.7	6.5	1.7	5.4	6.3
Forest	8.8	11.3	9.5	9.9	10.9	8.4	9.4	11.6	9.1
Savannah	8.0	2.3	1.0	7.8	2.6	1.4	8.9	2.0	1.1
Survey quarter (%)									
January-March	6.0†	6.2†	5.8†	6.2†	5.9†	6.2†	6.0†	6.7†	5.5†
April-June	3.9†	3.9†	4.4†	4.5†	4.2†	4.2†	3.8†	4.0†	4.3†
July-September	6.1†	5.9†	6.1†	5.8†	6.3†	5.4†	6.1†	5.6†	6.2†
October-December	4.0†	4.0†	3.8†	3.6†	3.6†	4.4†	4.1†	3.7†	4.0†

Data are shown as mean (standard deviation) unless otherwise stated. Overall *p*-values were calculated by X^2-test for categorical variables or *F*-test for continuous variables.
†Reflects not significant *p*-values that are ≥ 0.05

Table 3.4: Sociodemographic, economic, and environmental determinants of exploratory food expenditure patterns.

	'Traditional' $R^2 = 0.33$ *n* = 12,738		**'Processed foods' $R^2 = 0.36$ *n* = 12,738**		**'Food away from home' $R^2 = 0.34$ *n* = 12,738**		**Fish and seafood expenditure Logit model (1 = yes) *n* = 12,738**		**Log-transformed fish and seafood expenditure $R^2 = 0.48$ *n* = 11,994**	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**OR**	**95% CI**	**β**	**95% CI**
Head of household age (10-y)	0.202	0.171, 0.232	-0.031	-0.059, -0.003	-0.061	-0.083, -0.038	1.268	1.169, 1.374	0.101	0.088, 0.115
Female-headed household	0.586	0.507, 0.666	0.251	0.168, 0.333	-0.447	-0.509, -0.384	5.475	4.069, 7.366	0.212	0.169, 0.254
Head of household religion										
Christian	---	---	---	---	---	---	---	---	---	---
Muslim	-0.074	-0.215, 0.066	0.079	-0.028, 0.187	-0.133	-0.231, -0.034	---	---	---	---
Traditionalist	0.169	0.020, 0.317	0.272	0.136, 0.408	0.391	0.278, 0.504	---	---	---	---
Head of household ethnicity										
Akan	---	---	---	---	---	---	---	---	---	---
Ga-Dangme	---	---	---	---	0.061	-0.091, 0.212	1.644	0.956, 2.827	0.106	0.008, 0.204
Ewe	---	---	---	---	-0.083	-0.198, 0.032	1.443	0.962, 2.165	0.138	0.067, 0.209
Guan	---	---	---	---	-0.006	-0.152, 0.139	2.072	1.101, 3.900	0.013	-0.098, 0.125
Gurma	---	---	---	---	0.154	0.031, 0.277	2.260	0.921, 5.544	-0.033	-0.156, 0.091
Mole-Dagbani	---	---	---	---	0.015	-0.103, 0.133	1.679	1.082, 2.608	0.002	-0.071, 0.075
Grusi	---	---	---	---	0.107	-0.046, 0.260	1.768	0.939, 3.331	-0.017	-0.186, 0.153
Mande	---	---	---	---	-0.068	-0.260, 0.125	2.423	0.678, 8.657	-0.161	-0.344, 0.022
Other ethnic groups	---	---	---	---	-0.083	-0.264, 0.099	0.738	0.281, 1.940	-0.120	-0.280, 0.040
Household pregnancy	0.332	0.238, 0.426	---	---	-0.182	-0.255, -0.108	5.966	2.457, 14.489	---	---
Children in household under 5y	0.286	0.223, 0.348	0.110	0.050, 0.171	-0.300	-0.344, -0.257	2.498	1.639, 3.807	0.131	0.084, 0.177
Number of adult equivalents	---	---	-0.037	-0.056, -0.017	-0.121	-0.137, -0.105	3.358	2.649, 4.258	-0.061	-0.074, -0.049
Head of household secondary education	-0.148	-0.252, -0.043	0.250	0.152, 0.348	---	---	---	---	-0.128	-0.128, -0.075
Fishing, fish farming, or fish processing	---	---	---	---	---	---	0.198	0.083, 0.476	-0.211	-0.383, 00.039
Livestock ownership	---	---	---	---	---	---	---	---	---	---
Crops harvested	-0.152	-0.249, -0.055	-0.127	-0.205, -0.050	-0.124	-0.181, -0.067	3.321	2.113, 5.221	0.229	0.173, 0.284
Log monthly household income per AME	1.315	1.189, 1.442	1.220	1.103, 1.337	0.686	0.595, 0.777	1.917	1.493, 2.462	0.677	0.638, 0.716
Rural status	0.165	0.025, 0.304	---	---	-0.166	-0.237, -0.095	---	---	0.165	0.074, 0.256
Region									0.001	
Greater Accra	---	---	---	---	---	---	---	---	---	---
Western	-0.075	-0.298, 0.148	-0.160	-0.426, 0.106	-0.634	-0.822, -0.445	1.689	0.977, 2.920	0.481	0.321, 0.641
Central	0.212	-0.123, 0.546	0.196	-0.131, 0.524	-0.461	-0.645, -0.277	5.974	2.745, 13.002	0.338	-0.214, 0.461
Volta	-0.148	-0.370, 0.075	-0.134	-0.392. 0.123	-0.471	-0.665, -0.277	1.742	0.873, 3.475	0.162	0.037, 0.287
Eastern	0.054	-0.221, 0.329	-0.271	-0.518, -0.024	-0.615	-0.796, -0.434	2.538	1.379, 4.670	0.288	0.153, 0.423
Ashanti	-0.321	-0.587, -0.055	-0.518	-0.801, -0.236	-0.470	-0.685, -0.254	0.751	0.484, 1.165	-0.030	-0.223, 0.63
Brong Ahafo	-0.192	-0.436, 0.052	-0.476	-0.733, -0.220	-0.634	-0.822, -0.446	0.761	0.458, 1.265	-0.021	-0.141, 0.098
Northern	-0.110	-0.356, 0.137	0.147	-0.118, 0.413	-0.433	-0.651, -0.215	0.294	0.154, 0.561	-0.449	-0.584, -0.315
Upper East	-0.257	-0.257, -0.532	-0.239	-0.518, 0.040	-0.500	-0.723, -0.277	0.620	0.318, 1.210	-0.468	-0.618, -0.319
Upper West	0.066	0.066, -0.239	0.221	-0.078, 0.519	-0.216	-0.468, 0.035	0.837	0.423, 1.657	-0.542	-0.691, -0.392
Survey quarter (%)										
January-March	---	---	---	---	---	---	---	---	---	---
April-June	---	---	---	---	---	---	0.790	0.521, 1.199	-0.004	0.077, 0.920
July-September	---	---	---	---	---	---	0.513	0.355, 0.740	0.077	0.219, 0.283
October-December	---	---	---	---	---	---	0.638	0.418, 0.973	-0.125	-0.047, 0.002

Beta coefficients (β) and 95% confidence intervals (CIs) were calculated by multivariate linear regression models. Odds ratios were calculated by multivariate logistic regression models.

Table 3.5: Factor loadings of food groups for food expenditure patterns in Stage 1 of sensitivity analysis (fish and seafood divided into broad population or ecosystem groups).

Food groups	'Traditional'	'Processed foods'	'Food away from home'
Rice	0.01	0.09	-0.07
Other grains	-0.12	-0.11	0.09
Maize	-0.03	-0.01	-0.04
Processed grain products	0.04	0.35**	0.13
Baby food (Cerelac)	-0.02	0.08	0.01
Processed cassava	0.07	0.08	-0.01
Marine fish	0.19	0.05	-0.04
Freshwater fish	0.39**	-0.07	-0.03
Shellfish	0.26*	0.03	0.05
Other fish and seafood	-0.08	-0.05	0.17
Red meat	0.27*	-0.07	0.00
Poultry	0.07	-0.08	0.00
Processed meat	-0.16	0.09	-0.09
Other meat	0.08	0.07	-0.01
Milk	-0.03	0.39**	-0.01
Sweets	-0.13	0.43**	-0.05
Eggs	0.07	0.17	0.05
Oils and fats	0.08	0.13	-0.12
Vitamin A-rich fruit	0.29*	0.08	0.13
Other fruit	0.16	0.22*	0.26*
Dark green leafy vegetables	0.36**	-0.06	0.05
Vitamin A-rich vegetables	0.11	-0.01	0.03
Other vegetables	0.29*	0.06	-0.06
Nuts, seeds, and pulses	0.01	0.10	-0.07
White roots and plantains	0.44**	-0.05	0.00
Salt and spices	-0.11	0.04	-0.04
Coffee, tea, and cocoa drinks	-0.04	0.42**	0.03
Water	0.06	0.10	0.43**
Sodas and juices	0.02	0.20*	0.19*
Malt beverages	-0.08	0.08	0.16
Alcoholic beverages	-0.11	-0.34**	0.50**
Food away from home	-0.07	0.04	0.56**

**Factor loading ≥ |0.3|
*Factor loading ≥ |0.2|

Table 3.6: Factor loadings of food groups for three food expenditure patterns in Stage 2 of sensitivity analysis (fish and seafood divided into species/genera).

Food groups	‘Processed foods	‘Traditional’	‘Food away from home’
Rice	0.16	0.02	-0.07
Other grains	-0.03	-0.19	0.07
Maize	-0.04	0.01	-0.02
Processed grain products	0.34**	0.04	0.12
Baby food (Cerelac)	0.09	-0.02	-0.09
Processed cassava	0.01	0.08	0.00
Horse mackerel	-0.20*	0.10	0.06
Other marine fish	0.02	-0.04	-0.06
Herring	-0.18	0.06	0.01
Mackerel	0.11	0.17	-0.02
Shark	-0.02	-0.10	-0.05
Sardines	0.21*	-0.01	0.07
Tuna	0.12	-0.07	-0.10
Other freshwater fish	-0.03	0.51**	-0.05
Tilapia	-0.05	0.34**	0.08
Shrimp	0.02	-0.01	-0.01
Snails	-0.02	0.05	0.00
Crab	-0.03	0.00	0.02
Other fish and seafood	-0.06	0.01	0.18
Anchovy	0.25*	-0.07	-0.17
Other shellfish	-0.03	-0.07	-0.03
Red meat	0.01	0.17	-0.04
Poultry	-0.01	-0.03	0.01
Processed meat	0.16	-0.09	-0.07
Other meat	-0.02	0.10	0.00
Milk	0.36**	0.02	-0.02
Sweets	0.35**	-0.08	-0.02
Eggs	0.21*	0.08	0.03
Oils and fats	0.17	0.06	-0.11
Vitamin A-rich fruit	0.03	0.18	0.13
Other fruit	0.21*	0.12	0.25*
Dark green leafy vegetables	-0.05	0.28*	0.03
Vitamin A-rich vegetables	0.15	0.12	-0.02
Other vegetables	0.12	0.28*	-0.08
Nuts, seeds, and pulses	-0.01	-0.05	0.00
White roots and plantains	0.01	0.43**	-0.03
Salt and spices	0.12	-0.06	-0.02
Coffee, tea, and cocoa drinks	0.37**	-0.02	0.03
Water	0.10	0.11	0.42**
Sodas and juices	0.05	-0.09	0.25*
Malt beverages	0.14	-0.09	0.16

Alcoholic beverages	-0.13	-0.09	0.43**
Food away from home	0.03	-0.02	0.56**

**Factor loading ≥ |0.3|
*Factor loading ≥ |0.2|

Table 3.7: Sociodemographic, economic, and environmental determinants of food expenditure patterns in Stage 1 of the sensitivity analysis (fish and seafood divided into broad population or ecosystem groups).

	'Traditional' $R^2 = 0.30$		'Processed foods' $R^2 = 0.35$		'Food away from home' $R^2 = 0.35$	
	β	95% CI	β	95% CI	β	95% CI
Head of household age (10-y)	0.211	0.180, 0.242	---	---	-0.069	-0.095, -0.044
Female-headed household	0.533	0.453, 0.613	0.264	0.187, 0.341	-0.444	-0.509, -0.378
Head of household religion						
Christian	---	---	---	---	---	---
Muslim	---	---	0.110	0.006, 0.215	-0.119	-0.224, -0.013
Traditionalist	---	---	0.232	0.097, 0.367	0.381	0.261, 0.501
Head of household ethnicity						
Akan	---	---	---	---	---	---
Ga-Dangme	---	---	---	---	0.073	-0.084, 0.229
Ewe	---	---	---	---	-0.083	-0.202, 0.037
Guan	---	---	---	---	0.001	-0.148, 0.150
Gurma	---	---	---	---	0.148	0.018, 0.277
Mole-Dagbani	---	---	---	---	0.021	-0.097, 0.139
Grusi	---	---	---	---	0.116	-0.040, 0.273
Mande	---	---	---	---	-0.077	-0.282, 0.127
Other ethnic groups	---	---	---	---	-0.090	-0.269, 0.089
Household pregnancy	0.331	0.228, 0.434	---	---	-0.180	-0.256, -0.103
Children in household under 5y (%)	0.277	0.212, 0.342	0.129	0.070, 0.189	-0.298	-0.345, -0.252
Number of adult equivalents	---	---	-0.033	-0.052, -0.013	-0.120	-0.137, -0.104
Head of household secondary education	-0.129	-0.236, -0.021	0.230	0.136, 0.324	---	---
Fishing, fish farming, or fish processing	---	---	---	---	---	---
Livestock ownership	---	---	---	---	---	---
Crops harvested	-0.120	-0.222, -0.017	-0.144	-0.223, -0.066	-0.122	-0.183, -0.060
Log monthly household income per AME	1.234	1.106, 1.362	1.177	1.061, 1.292	0.728	0.631, 0.826
Rural status	0.174	0.023, 0.325	---	---	-0.182	-0.262, -0.103
Region						
Greater Accra	---	---			---	---
Western	---	---	-0.115	-0.383, 0.152	-0.649	-0.843, -0.454
Central	---	---	0.249	-0.078, 0.577	-0.420	-0.611, -0.229
Volta	---	---	-0.160	-0.413, 0.093	-0.488	-0.687, -0.289
Eastern	---	---	-0.295	-0.538, -0.052	-0.570	-0.763, -0.377
Ashanti	---	---	-0.487	-0.762, -0.213	-0.473	-0.704, -0.242
Brong Ahafo	---	---	-0.448	-0.701, -0.194	-0.643	-0.837, -0.450
Northern	---	---	0.166	-0.095, 0.427	-0.397	-0.624, -0.171
Upper East	---	---	-0.187	-0.459, 0.085	-0.461	-0.691, -0.231
Upper West	---	---	0.219	-0.076, 0.514	-0.199	-0.460, 0.063
Survey quarter (%)						
January-March	---	---	---	---	---	---
April-June	---	---	---	---	---	---
July-September	---	---	---	---	---	---
October-December	---	---	---	---	---	---

Beta coefficients (β) and 95% confidence intervals (CIs) were calculated by multivariate linear regression models.

Table 3.8: Sociodemographic, economic, and environmental determinants of food expenditure patterns in Stage 2 of the sensitivity analysis (fish divided into species/genera).

	'Processed foods' $R^2 = 0.38$		'Traditional' $R^2 = 0.31$		Food away from home' $R^2 = 0.35$	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
Head of household age (10-y)	-0.035	-0.061, -0.009	0.198	0.168, 0.229	-0.082	-0.109. -0.056
Female-headed household	-0.245	0.161, 0.329	0.484	0.402, 0.566	-0.442	-0.510, -0.375
Head of household religion						
Christian	---	---	---	---	---	---
Muslim	0.045	-0.062, 0.151	---	---	-0.095	-0.203, 0.013
Traditionalist	0.323	0.175, 0.471	---	---	0.366	0.248, 0.484
Head of household ethnicity						
Akan	---	---	---	---	---	---
Ga-Dangme	---	---	---	---	0.051	-0.105, 0.208
Ewe	---	---	---	---	-0.071	-0.194, 0.053
Guan	---	---	---	---	-0.035	-0.178, 0.108
Gurma	---	---	---	---	0.135	0.010, 0.260
Mole-Dagbani	---	---	---	---	0.007	-0.116, 0.129
Grusi	---	---	---	---	0.132	-0.025, 0.289
Mande	---	---	---	---	-0.122	-0.346, 0.103
Other ethnic groups	---	---	---	---	-0.094	-0.276, 0.089
Household pregnancy	---	---	0.247	0.160, 0.334	-0.180	-0.257, -0.102
Children in household under 5y (%)	0.097	0.034, 0.159	0.201	0.135, 0.268	-0.376	-0.424, -0.328
Number of adult equivalents	-0.027	-0.047, -0.006	-0.019	-0.038, -0.001	-0.115	-0.132, -0.099
Head of household secondary education	0.300	0.202, 0.399	-0.104	-0.205, -0.002	---	---
Fishing, fish farming, or fish processing	---	---	---	---	---	---
Livestock ownership	---	---	---	---	---	---
Crops harvested	-0.222	-0.322, -0.121	---	---	-0.105	-0.165, -0.046
Log monthly household income per AME	1.326	1.206, 1.447	1.182	1.063, 1.301	0.690	0.593, 0.787
Rural status	---	---	0.237	0.059, 0.415	-0.174	-0.252, -0.095
Region						
Greater Accra	---	---	---	---	---	---
Western	-0.361	-0.689, -0.033	-0.059	-0.261, 0.142	-0.581	-0.770, -0.393
Central	0.247	-0.106, 0.599	-0.223	-0.458, 0.011	-0.455	-0.643, -0.266
Volta	-0.177	-0.434, 0.079	0.232	0.012, 0.453	-0.391	-0.588, -0.195
Eastern	-0.180	-0.423, 0.064	0.275	-0.073, 0.623	-0.522	-0.712, -0.332
Ashanti	-0.466	-0.739, -0.193	-0.133	-0.380, 0.114	-0.431	-0.667, -0.196
Brong Ahafo	-0.453	-0.708, -0.199	0.113	-0.086, 0.313	-0.572	-0.763, -0.381
Northern	0.239	-0.033, 0.511	-0.018	-0.237, 0.202	-0.350	-0.575, -0.126
Upper East	-0.216	-0.508, 0.077	-0.236	-0.473, 0.000	-0.383	-0.614, -0.151
Upper West	0.568	0.237, 0.900	0.044	-0.233, 0.320	-0.321	-0.592, -0.050
Survey quarter (%)						
January-March	---	---	---	---	---	---
April-June	---	---	---	---	---	---
July-September	---	---	---	---	---	---
October-December	---	---	---	---	---	---

Beta coefficients (β) and 95% confidence intervals (CIs) were calculated by multivariate linear regression models.

Chapter 4 Assessing the Consumer Demand for Fish and Seafood Species/Genera in Ghana

4.1 Introduction

Fish and seafood is an important source of food and nutrition in many low- and middle-income countries (LMICs) where its contribution to overall protein intake can exceed 20% (1). In these settings, fish and seafood often comprise many species/genera that are produced by gleaning, wild capture, or aquaculture that are in marine or freshwater ecosystems. This biodiversity can influence consumer behaviors as preferences for variations in the factors emerge. Lower income consumers might choose small indigenous fish species that provide higher vitamin A, iron, calcium, and zinc content than the flesh portions of larger farmed fish (2). On the other hand, higher income consumers might prefer larger farmed species/genera (3,4) despite their lower micronutrient content (5).

Ghana is a lower-middle-income country in West Africa that is dependent on its marine and freshwater fisheries and aquaculture. Ghana's fisheries sector produces approximately 440,000 tons of fish and seafood annually (6), which contributes over 60% of household animal protein expenditure (7). Yet, Ghana's food system is rapidly transforming (8,9) amidst societal shifts that change consumer behaviors toward fish and seafood. Increasing incomes and an urbanizing population are associated with higher meat consumption (10,11), which could include or substitute for fish and seafood. International companies are opening new supermarkets in Ghana's growing urban areas (12), but research indicates non-wealthy consumers still prefer traditional open air food markets (13). Finally, the recent near collapse of Ghana's marine forage fish stocks (14,15) and the resulting fisheries closures designed to rehabilitate them (16,17) will impact the national fisheries sector for years to come. At the same time, national policies have been implemented to drastically scale-up freshwater aquaculture production in Lake Volta (18), as well as protecting domestic tilapia production through an import ban (19,20).

Given the importance of fish and seafood amidst Ghana's dynamic food system, metrics that track consumer demand responses to income and price changes are imperative for effective fisheries policies and management that considers consumer welfare (21). By incorporating information on fish and seafood species/genera, or biodiversity, these metrics will better reflect the heterogenous nature of fish and seafood in Ghana and their associated consumer behaviors (22). Previous research on consumer demand in Ghana generally finds that fish and seafood expenditure has a positive, inelastic relationship with income and a negative inelastic relationship with fish and seafood prices (23–29). But, the analytic frameworks used by these studies vary widely by estimation procedure, such as by addressing a potential nonlinear relationship between income and food budget shares or the selection bias caused by zero expenditure on food items. Moreover, none of the studies considered fish and seafood species/genera or even combined them with other animal flesh foods, thereby occluding our ability to assess heterogeneity in fish and seafood demand. This heterogeneity is especially important for nutrition monitoring, as nutrient levels can vary highly for polyunsaturated fatty acid, calcium, iron, zinc, and vitamin A, among others (1,30).

Other research on Asian contexts have disaggregated fish and seafood by species/genera and found differences in income and price responses (21,31), as with disaggregating red and other meat products in Ghana (28). This study harnesses the analytical framework of the Dey et al (2011) study of fish and seafood consumer demand in Bangladesh (21) to provide detailed estimates of consumer behaviors of fish and seafood in Ghana. When estimating the income and price elasticities of demand, we consider two approaches to incorporating fish and seafood biodiversity into demand system modeling and compare their results. To our knowledge, this is the first study to estimate income and price elasticities for fish and seafood species/genera in Ghana and one of the first in Africa (32,33).

4.2 Methodology

4.2.1 Data source

This study analyzes household budget data that was collected as part of the seventh round of the Ghana Living Standards Survey (GLSS) by the Ghana Statistical Service. The purpose of the GLSS is to collect detailed nationally representative household-level information on education, health, household, food and non-food consumption expenditure, among other sociodemographic topics. The GLSS is conducted approximately every five years; each round focuses on a specific topic. The seventh round of the GLSS was focused on agriculture. Data was collected by trained interviewers over 12 months from October 2016 to September 2017. The survey defined households as comprised of individuals living together in the same unit who share housekeeping and cooking arrangements. The total sample of the GLSS 7 was 14,009 households that were drawn from 1,000 enumeration areas. These enumeration areas were divided proportionally by urban or rural status and across Ghana’s 10 administrative regions.

Household consumption expenditure was assessed using a combination of self- and interviewer-administered survey tools over six household visits during a one-month duration. At the initial household visit, an enumerator instructed a literate household member to record daily food and non-food consumption expenditure. During the five subsequent visits, the enumerator reviewed the diaries with the household member responsible for food purchases against a predefined list of food items. While some of the food items were measured in grams or kilograms, many were measured using nonstandard units, such as American olonka tins, margarine tins, sardine tins, heaps, bowls, balls (for corn dough, primarily), and beer bottles. In order to convert these nonstandard units to grams or kilograms, we built a unit conversation table that amalgamated the GLSS 7 unit conversion table with an older resource on food weights and handy measures (34).

After converting food consumption into grams or kilograms, we calculated monthly household food consumption expenditure per capita by adding up the six assessments and dividing that sum by the number of adult equivalents in the household. We winsorized monthly consumption expenditure at the 99th percentile to remove outliers and coded missing consumption expenditure as zeros to retain the sample size. We used the adult equivalent scale that came predefined in the GLSS 7 dataset, which considers lower calorie requirements for infants and children. To calculate food prices, we first used a unit value approach by dividing household expenditure by consumption quantity. Since this approach provides limited coverage in that it only calculates prices for purchased food items, we smoothed the food prices over enumeration areas by calculating the geometric means. If we were unable to calculate enumeration area-level prices because no households purchased a given food item, we further smoothed the prices over districts then regions divided by urban and rural strata (e.g., we used rural Central region and urban Central region instead of one Central region). Finally, food prices that were still missing were filled in with the food price sheet included with the GLSS 7. This data source was used last resort because it presented a limited range of food items and enumeration areas.

There were nearly 26 fish and seafood species/genera consumed by the household sample. Since it was infeasible to analyze all the species/genera due to very low consumption quantities of some food items, we aggregated species/genera using two different approaches. The first approach was to create high level fish and seafood groups that distinguish between ecosystem and taxonomy, which yielded four distinct groups: marine fish and seafood, freshwater fish and seafood, shellfish, and other fish and seafood, which were fish and seafood items of indeterminate production source or species/genera. The second approach retained species/genera information and yielded 10 distinct groups (see Table 1.). We first referred to the food list in the GLSS 7 survey documentation and combined food items of the same species/genera. For example, we combined distinct items like smoked mackerel and separate brands of canned mackerel in tomato sauce into one mackerel group; similarly, we combined dried tilapia and fresh/frozen tilapia into one tilapia group. We also grouped less commonly consumed species/genera by taxonomy; for example, combining shrimp, crab, and snails into one shellfish group. Finally, the GLSS 7 food list had an 'other fish' food item that allowed write-in responses. For these, we reviewed the qualitative data and matched each write-in response with an existing food list item; unmatched responses were categorized as 'other fish and seafood'.

4.2.2 Analytical approach

We used a multistage budgeting framework to analyze the consumption behaviors of Ghanaian households for fish and seafood. As noted by Dey et al. (2011), from which this study borrows heavily, the multistage framework reduces the number of equations that are estimated by segregating the target fish and seafood species/genera and protein-rich foods from food and non-food expenditure (18). (See **Error! Reference source not found.**.) This vastly improves the e fficiency of the analysis than if food and non-food consumption expenditure was included in one demand system.

4.2.2.1 Stage 1: food and non-food expenditure

The first stage of the budgeting framework is to estimate household food expenditure as a function of food and non-food prices, household income, and a vector of sociodemographic variables using multivariable linear regression:

$$\ln M = \alpha_0 + \alpha_1 \ln P_f^* + \alpha_2 \ln I + \alpha_3 (\ln I)^2 + \alpha_4 NF + \alpha_5 HAE + \sum_{i=1}^{9} \delta_i R_i + \sum_{i=1}^{3} \varphi_i SQ_i + \lambda C + \varepsilon$$

where ln is the natural logarithm, M is monthly per capita food expenditure (in Ghanaian cedis); I is monthly per capita income (in cedis); NF is monthly per capita non-food expenditure (in cedis); HAE is household adult equivalents (number); R_i are dummy variables for Ghana's 10 administrative regions (Accra is the referent); SQ_i are the dummy variables for survey quarters (January-March is the referent); C is for rural status (1 = rural; 0 = urban); and α, δ, φ, and λ are the corresponding parameters to be estimated. In line with Dey et al. (2011), we included a quadratic income term to potentially address a nonlinear association between income and food consumption (21). We calculated the Stone Price Index of food ($\ln P_f^*$) as:

$$\ln P_f^* = \sum_{j-1}^{m} w_j \ln Pfd_j$$

where w_j is the expenditure share and Pfd_j is the price of commodity j.

4.2.2.2 Stage 2: protein-rich food expenditure

The second stage builds on the first by estimating household expenditure on a protein-rich food basket as a function of the food prices, monthly per capita food expenditure, and the same vector of sociodemographic variables as in the first stage using multivariable linear regression:

$$\ln HPF = \theta_0 + \sum_{i=1}^{k} \beta_i \ln Pfd + \theta_1 \ln M^* + \theta_2 (\ln M)^2 + \theta_3 HAE + \sum_{i=1}^{9} \delta_i R_i + \sum_{i=1}^{3} \varphi_i SQ_i + \lambda C + \varepsilon_i$$

where *HPF* is monthly per capita protein-rich food expenditure (in cedis); Pfd_i is the price of commodity *i*, being red and other meat, poultry, eggs, nuts, seeds, and pulses, and fish and seafood; *M** is the predicted monthly per capita food expenditure that we ascertained from the first stage of the budgeting framework, and the suite of sociodemographic variables.

4.2.2.3 Stage 3: fish and seafood species/genera

In the third stage, we estimated the demand for the aggregated and disaggregated fish and seafood groups using quadratic almost-ideal demand system (QUAIDS) models. The QUAIDS model is based on the almost-ideal demand system (AIDS) model, which uses consumer demand and utility theories to establish that a rational consumer's expenditure on a set of goods explains how they achieve maximum utility, or benefits, under income and price constraints (35). The AIDS model was refined by Banks et al. (1997) by adding a quadratic term to account for nonlinear consumer expenditure (36). For instance, consumer demand for meat among low-income households is highly responsive to changes in market prices, whereas demand is more rigid for middle- or high-income households.

A sizable proportion of the household sample exhibited zero expenditures for several fish and seafood species/genera. If these households with zero expenditures were excluded in the demand system, the resulting parameter estimates would reflect the consumer behaviors of households who had already decided to purchase fish and seafood, regardless of income and price effects, instead of all households who factor income and price into their initial decision to buy. To account for this selection bias, we followed Dey (2000), Garcia et al., (2005), and Dey et al. (2011) to introduce a correction term called the Inverse Mill's Ratio (IMR) (21,37,38). This correction term is specified using a Heckman two-step procedure (39), where the first step uses a Probit model to estimate the probability that a household will consume the food item. In the second step, the IMR is calculated by dividing the density probability function by the cumulative probability function and incorporated into the QUAIDS model:

$$w_i = \tau_{i0} + \sum_{j=1}^{k} \mu_{ij} \ln P_j + \nu_{i1} \ln(PRF^*/P^*) + \nu_{i2} \ln[(PRF^*/P^*)]^2 + \theta_3 HAE + \sum_{i=1}^{9} \delta_i R_i + \sum_{i=1}^{3} \varphi_i SQ_i + \lambda_i C + \pi_i IMR + \varepsilon_i$$

where w_i are the expenditure shares for each protein-rich food group, Pj is the vector of food prices, P^* is the Stone Price Index of protein-rich foods, and $PRF^*/P^*$is the predicted protein-rich food expenditure calculated in the second stage that we deflated by the price index. We also included a quadratic term to address nonlinearity in protein-rich food purchasing.

We constructed three QUAIDS models. The first model estimated fish and seafood demand against other protein-rich foods; the second model disaggregated fish and seafood into marine fish, freshwater fish, shellfish, and other fish groups; the third and final model disaggregated fish and seafood into distinct species/genera. We developed the QUAIDS model in Stata by using the

QUAIDSce package (40), which is builds off the QUAIDS package (41), but accounts for zero expenditure, i.e. censored data. The demand elasticity formulas that the QUAIDSce package uses during postestimation are specified below, which uses the derivatives of the protein-rich food expenditure share equation:

$$l_i = \frac{\partial w_i}{\partial \ln u_i} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{u_i}{a(p)}\right]\right\}$$

$$l_{ij} = \frac{\partial w_i}{\partial \ln(p_j)} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_{t=1}^{K}\gamma_{ji}\ln p_i\right)\frac{\lambda_i\beta_j}{b(p)}\left\{\ln\left[\frac{u_i}{a(p)}\right]\right\}^2$$

The expenditure elasticity equation follows:

$$e_i = 1 + \frac{l_i}{w_i}$$

Marshallian or uncompensated price elasticities, which factor substitution and income, are calculated using the following equation:

$$e_{ij}^{u} = \frac{l_{ij}}{w_i} - \delta_{ij}$$

where δij is the Kronecker Delta that takes the value $\delta = 1$ if $i = j$ for own-price elasticities and $\delta = 0$ if $i \neq j$ for cross-price elasticities (31). Own-price elasticities are interpreted as the change in a demand for a specific food item in response to a 1% change in that food item's price. Cross-price elasticities are interpreted as the change in demand for a specific food item in response to changes in another food item's market prices. Two food items with opposing demand directions are considered substitutes; two food items with the same demand directions are considered complements. The Hicksian or compensated price elasticities, which only factor substitution, can be calculated using the following equation:

$$e_{ij}^{c} = e_{ij}^{u} + w_j e_i$$

We calculate both types of price elasticities, as income effects might be especially large for foods that occupy a high budget share and consumer demand is highly responsive to changes in income (42), such as the case of fish in Ghana (7).

4.2.3 Results

4.2.3.1 Fish and seafood consumption patterns in Ghana

The weighted average prices of fish and seafood species/genera are presented in Table 4.1. Most of the fish and seafood species/genera were more expensive than other types of protein-rich foods. Sardines stood out as the most expensive by weighted average price, possibly due to the influence their relatively low consumption had on the weighting procedure, as well as their canned processing which might enhance the product value. Mackerel was the next most expensive fish and seafood, followed by other freshwater fish.

We estimated that household consumption of fish and seafood per adult equivalent to be 1.5 kg/month. This is lower than previous estimates of 2.2 kg/month (26 kg/year per capita) (43), though calculations certainly vary based on the data available and estimation method. For example, in this analysis, we used the adult equivalent variable to account for different caloric requirements by life stage and sex, whereas other analyses use food balance sheet data that is aggregated at the national level. The share of fish and seafood in total expenditure on protein-rich foods was 69.7%. This estimate is higher than what Sumberg et al. (2016) calculated by analyzing food expenditure data from the sixth round of the GLSS, though their analysis excluded pulses, nuts, and seeds and totaled animal protein sources instead (7).

There is a clear positive trend between income quartile and the quantities of fish and seafood consumption that persists across several species/genera (Table 4.2). Mackerel and other marine fish showed the largest differences in consumption quantities between the lowest and highest income quartiles; herring showed the smallest difference. Total monthly fish and seafood consumption quantities only differed between urban households by 0.10 kg per capita but greatly varied by species/genera. Urban households consumed higher quantities of mackerel and other marine fish than rural households, but lower quantities of herring and other freshwater fish. Overall fish and seafood expenditure decreased by income quartile by 14 percentage points. The overall share of protein-rich food expenditure increased by income quartile for mackerel and other marine fish but decreased for herring and other freshwater fish.

4.2.3.2 Parameter estimates of the food and protein-rich food expenditure models

We present the parameter estimates from the Stage 1 food expenditure function in Table 4.3. Most of the variables exhibited statistically significant associations with food expenditure. The Stone Price Index was positively associated with food expenditure, indicating that household spending increases when food is more expensive. The linear and quadratic terms of total household expenditure per capita were both positively associated with food expenditure. Though the magnitude of association for the quadratic term is smaller, the statistically significant association supports a nonlinear relationship in which food spending tapers off as incomes rise. Rural status was positively associated with food spending, as well as most of the region dummy variables. None of the associations with survey quarter variables were statistically significant, which supports that households do not change their food spending depending on the period of the year they were surveyed.

Next, we estimated the protein-rich food expenditure function in Stage 2. Similar to Stage 1, we found that most of the explanatory variables yielded statistically significant associations with protein-rich food expenditure (Table 4.4). The variables representing the prices of cereals, grains, and starchy staples and fruits and vegetables were both negatively associated with protein-rich food expenditure; however, there was no association with the price of protein-rich foods itself. Food expenditure was negatively associated with protein-rich food expenditure, but the quadratic term was positively associated. This “U” shape relationship could mean protein-rich food expenditure decreases when households spend less on food, but eventually increases after reaching a nadir. The survey quarter dummy variables representing April-June and July-September were both positively associated with protein-rich food expenditure. Notably, the July-September quarter coincides with the bumper fishing season, which could explain the increase in protein-rich food spending (22,25).

4.2.3.3 Expenditure elasticities of demand

We present the expenditure elasticities for protein-rich food groups, fish and seafood groups, and fish and seafood species/genera in Table 4.5. All expenditure elasticities are positive, indicating that the quantities demanded change in the same direction as total household expenditure. In Stage 2, we estimated the expenditure elasticity for protein-rich foods to be 1.63, which indicates that a 1% rise in total expenditure will result in a 1.63% increase in the quantity demanded. In Stage 3, we found that expenditure elasticities varied amongst different types protein-rich foods. Red and other meat and eggs were expenditure elastic, yielding higher magnitudes (1.26 and 1.59, respectively) than poultry, pulses, nuts, and seeds, and fish and seafood (1.03, 1.10, and 0.90, respectively). On the other hand, fish and seafood expenditure inelastic with an estimate of 0.90, meaning the rate of increase in quantity demand is smaller than the rate of increase in prices. In Stage 3A, we disaggregated fish and seafood into marine fish, freshwater fish, shellfish and other fish. Marine fish and freshwater fish both exhibited unitary expenditure elasticities with estimates of around 1.00. In Stage 3B, we disaggregated fish and seafood into species/genera to find some differences between these expenditure elasticities and their Stage 3A analogs. For example, the expenditure elasticity for marine fish in Stage 3A was 1.01, but the expenditure elasticity for sardines in Stage 3B was 0.61.

4.2.3.4 Price elasticities of demand

In Table 4.6, we present the uncompensated and compensated own-price elasticities of demand for protein-rich foods groups, fish and seafood groups, and fish and seafood species/genera. As expected, all own-price elasticities are negative, signaling their negative relationships between commodity prices and quantities demanded. For most of the protein-rich food groups, the magnitudes of the uncompensated own-price elasticities are larger than their compensated own-price elasticities. This is because the uncompensated elasticities include the effects of income in their total estimates, whereas compensated elasticities exclude the effects of income and report the effects attributable to price changes only. We observe this difference in Stage 2, where protein-rich foods are own-price inelastic, but the uncompensated elasticity estimate is -0.76 and the compensated elasticity estimate is -0.58.

In Stage 3, the compensated own-price elasticities indicate that all protein-rich foods are inelastic, except for eggs. For fish and seafood, the compensated own-price elasticity is nearly 65% lower than the uncompensated elasticity, indicating that consumers are not as responsive to changes in fish and seafood prices when the income effect is removed. In Stage 3A, where we disaggregated fish and seafood into four groups, we find that only shellfish is inelastic with a compensated own-price elasticity estimate of -1.20, while marine fish, freshwater fish, and other fish and seafood are inelastic. Similar to Stage 3, in Stage 3A, we also find that the compensated own-price elasticity for marine fish is over 50% lower than the uncompensated elasticity. Finally, in Stage 3B, the compensated own-price elasticities for vary by fish and seafood species/genera. The compensated elasticities for tuna and shellfish are elastic; all other species/genera are inelastic, though at varying degrees. The compensated own-price elasticities for mackerel and herring and approximately 20% lower than their uncompensated elasticities; the compensated and uncompensated elasticities are approximately the same for sardines, tuna, small oily marine fish, tilapia, shellfish, and other fish and seafood.

We then estimated the cross-price elasticities of demand for protein-rich food groups (Table 4.7), fish and seafood groups (Table 4.8), and fish and seafood species/genera (

Table 4.9), where the columns denote 1% changes in the price of that food and the rows are the associated changes in consumption. Cross-price elasticities that are positive indicate substitutability between goods. For example, in Table 4.7, we observe that a 1% increase in the price of red and other meat is associated with a 0.19% increase in the quantity of poultry demanded; supporting that consumers substitute poultry for red and other meat. Estimates that are negative indicate complementarity. Also in Table 4.7, we observe that a 1% increase in the price of eggs is associated with a 0.28% decrease in the quantity of pulses, nuts, and seeds demanded; consumers change their consumption for these two goods in the same negative direction.

Across all the stages, most compensated cross-price elasticities are positive, indicating that most protein-rich foods are substitutes for each other. In Stage 3 (Table 4.7), we observe that each protein-rich food group is a substitute for fish and seafood; the highest magnitude elasticity estimate is eggs (2.39), followed by red and other meat (1.28), pulses, nuts, and seeds (1.16), and poultry (0.96). In Stage 3A (Table 4.8), we observe that all protein-rich food and fish and seafood groups are substitutes for marine and freshwater fish, except for shellfish, which is a complement with freshwater fish. None of the food groups are substitutes or complements with shellfish, as their cross-price elasticities are approximately unitary. Finally, in Stage 3B (

Table 4.9), there are only commodities which exhibit negative cross-price elasticities describing complementary relationships. Sardines are complements with mackerel, herring, and other marine fish; Tuna is a complement with tilapia; and shellfish is a complement with sardines.

4.3 Discussion

In this study, we analyzed recent household consumption expenditure data from the GLSS 7 to assess consumer demand for 10 fish and seafood species/genera in Ghana. For each species/genera, we estimated their shares of total protein-rich food expenditure, expenditure elasticities of demand, and own- and cross-price elasticities of demand. Previous research often fails to incorporate fish and seafood biodiversity by 1.) aggregating species/genera into one fish and seafood group, or 2.) aggregating fish and seafood with other animal flesh foods (i.e., meat). These analyses provide useful information to compare food demand at a population level. However, they preclude linking their results to other food systems components where information on species/genera is required (21). Some use cases include fisheries policies that set annual catch limits for individual stocks, public health surveillance of food safety risks or the population prevalence of nutrient adequacy, or food sustainability modeling that uses life cycle assessments to derive greenhouse gas footprints.

We estimate that fish and seafood accounts for nearly a quarter of household food budgets and nearly 70% of spending allocated to protein-rich foods, underscoring the importance of fish and seafood in Ghana. Out of all protein-rich foods, fish and seafood is expenditure inelastic and has the lowest expenditure elasticity at 0.90 (Table 4.5). This estimate is consistent with previous research that also used demand system models to analyze earlier rounds of the GLSS (estimates range from 0.70 to 0.89) (23,24,26,28). Our estimate is slightly larger than the others, which could be explained by differences in methodological features of the demand system models. We used a censored Quadratic Almost Ideal Demand System model that accounted for the nonlinear relationship between household income and food spending and used a Heckman two-step procedure to correct for the selection bias introduced by zero expenditures. In other research, Ackah & Appleton (2007), Osei Asare & Eghan (2013), and Akpalu & Okyere (2023) used a similar demand system model called a Linear Approximation Almost Ideal Demand System (LA/AIDS) and they forwent including a quadratic income term. Osei-Asare & Eghan (2013) used the Heckman two-step procedure to address zero expenditures, but Ackah & Appleton (2007), Ansah et al. (2020), Akpalu & Okyere (2023) do not. Another study illustrates the importance of distinguishing fish and seafood from other animal flesh foods. Pacem (2018) uses a QUAIDS model to estimate the demand for meat and fish in northern Ghana (29). The expenditure elasticities that they calculated by income quartiles ranged from 1.42 to 1.71, which are similar to the estimate of 1.63 that we calculated for the combined protein-rich food group. This stark difference between expenditure elasticities for protein-rich foods versus fish and seafood, as well as their designations as elastic and inelastic, respectively, highlight the value of more disaggregated food data for the Ghanaian context.

We estimated that the compensated own-price elasticity for fish and seafood was -0.40 (

Table 4.6), which matches other research that produced estimates ranging from -0.30 to -0.84 (23,24,26). The own-price inelastic nature of fish and seafood suggests that its overall contribution to diets would be stable under price inflation. In terms of nutrition, this signals that the household supply of protein would remain intact, as protein content is relatively invariant between species/genera (2). On the other hand, food price inflation could force fish and seafood consumers to spend more of their income on food.

In subsequent stages of the analysis where we disaggregated fish and seafood by species/genera, the lowest absolute value estimates for compensated own-price elasticities correspond to mackerel (-0.75), herring (-0.81), and sardines (-0.81). While all three fishes are affected by the small pelagics fishery closure implemented annually by the Ministry of Fisheries and Aquaculture Development (16), its overall impact on consumer welfare might differ by socioeconomic status and consumer behaviors. For instance, mackerel and herring exhibit opposing consumption trends (Table 4.2): mackerel appeals to higher income consumers, as evidenced by its highest shares of protein-rich food expenditures in the highest income quartiles; herring appeals to lower income consumers, as its shares are highest in the lowest income quartiles. While both fishes are own-price inelastic, consumers who favor herring might be more severely impacted by price increases as a function of their smaller incomes. Contrary to mackerel and herring, sardine consumption might be unaffected since all the expenditure observations for sardines were for brands of canned products. While the country origin is unknown, many of the brands' manufacturers (Titus, Princess, and Obaapa) are based in Morocco (44), a prominent source of Ghana's fish and seafood imports (45). Since the sardines are preserved for a long shelf life, consumers who purchase sardines might be resilient to short-term price fluctuations.

While many fish and seafood species/genera are substitutes for mackerel, shellfish and tilapia exhibited the highest cross-price elasticity estimates (0.53 and 0.24, respectively) (

Table 4.9). Research indicates that urban consumers exhibit mixed preferences for shellfish, which we defined as crab, shrimp, lobster, snail, and oyster. Gyampoh et al. (2020) found that middle-income consumers living in Accra purchase shrimp and blue crab caught on the southeastern coast of Ghana (46). Likewise, Hayford (2021) found that middle-income consumers living in an Accra fishing community preferred oysters over eggs, meat, and poultry (47). While snail meat is considered a delicacy in southern Ghana, over half of urban consumers living in Tamale, a northern city, do not eat it, with the most common reason being undesirable texture (48). Over the past decade, tilapia production in Ghana has sharply increased, in large part due to government policies incentivizing aquaculture in Lake Volta and a ban on tilapia imports (18–20). Our findings show that tilapia consumption is relatively low (Table 4.2), but that its consumer base is buffered by stronger preferences for mackerel and herring. Given the small pelagics fishery closure, consumers may substitute tilapia if mackerel and herring prices rise. Since farmed fish are often less nutrient dense (5), food and nutrition policy would need to communicate dietary recommendations that fill gaps in micronutrient intake.

Similar to mackerel, many other fish and seafood species/genera were substitutes for herring. The highest cross-price elasticity estimate was for tuna (0.55), which is own-price elastic (-1.56) and a substitute for every fish and seafood/genera except tilapia. In Ghana, tuna can be caught locally or imported and processed by freezing, smoking, or canning (49). While we found that tuna is one of the least consumed fish and seafood species/genera in the sample (Table 4.2), smoked tuna is used in the main dishes served in Homowo, an annual harvest festival celebrated by the Ga ethnic group (50). This prized status could motivate its price elastic nature and role as a substitute. For example, consumers might switch to tuna when prices for other fish and seafood rise, but they dramatically modify their consumption when tuna prices rise, too.

Finally, we observe that consumers exhibit a mixed hierarchy of preferences for fish and seafood species/genera interspersed with other protein-rich foods. In one example, the cross-price elasticities of red and other meat indicate its substitutability for mackerel (0.22), herring (0.23), and tilapia (0.19). Currently, Ghana relies on imports from the EU and Burkina Faso to satisfy the majority of consumer demand for cattle meat (45,51). If consumer demand increases, these imports will need to grow or local production that relies traditional free-range systems (52) will need to intensify. Moreover, the notion of consumers switching from nutrient dense oily marine fish to red meat runs counter to Ghana's food-based dietary guidelines, which promote consumption oily marine to protect against cardiovascular diseases (53). In a second example, the cross-price elasticities of eggs support its role as a substitute for herring (0.27) and other freshwater fish (0.23). In Ghana, nearly all egg consumption comes from domestic sources (45) that rely on small- and medium-scale production (54). Moreover, nutrition education programs promote egg consumption as promising ventures to mitigate child undernutrition (55). When these nuances are ignored, policymakers lose valuable food systems information that can be used to design and implement multisectoral nutrition programs. In fact, in Stage 3 of the analysis, which analyzed one broad fish and seafood group, the cross-price elasticity estimate for eggs is nearly twice the estimate of red and other meat (2.39 and 1.28, respectively). If using this aggregated information alone, policymakers might only consider the substitution effect of eggs on domestic production and undernutrition, rather than simultaneous considerations for red meat imports and chronic disease.

4.4 Strengths, Limitations, & Policy Implications

One prominent strength of this study is the use of household data from the seventh round of the Ghana Living Standards Survey. In this round, enumerators collected the household consumption expenditure data using a highly disaggregated food list, which contained information on biodiversity, food processing, and company brand information. This detailed information allowed us to construct the fish and seafood species/genera groups, thus enabling the main analysis which was heretofore unachievable due to data constraints.

Another strength is the use of a censored Quadratic Almost Ideal Demand System. This demand system estimation method addresses two principal challenges when analyzing household consumption expenditure data survey data, which previous research in Ghana rarely address at the same time First, we account for potential nonlinear associations between household income and budget allocation. For food, these relationships are commonly parametric (56); for example, starchy staples represent the majority of food expenditures at lower incomes but plateau and diminish at higher incomes. Second, we correct for the selection bias introduced by zero expenditures. As noted in the methodology, in a non-censored model, households with zero expenditures would be excluded from the analysis due to incomplete data. This introduces a selection bias toward households who can allocate their food budgets to higher priced goods. Practically, it also immensely reduces the sample size and makes estimating consumer demand for uncommonly purchased foods impossible.

This study had a couple limitations. First, the elasticity of demand estimates are cross-sectional in nature, meaning they do not establish causality in consumer responses to income and food price increases. Another limitation is that our focus on fish and seafood biodiversity forfeited incorporating information on other important factors that influence consumer demand. For example, we combined expenditures on canned tuna and tuna purchases in open market settings into one tuna species/genera group. While this allows us to compare tuna to other marine fish and seafood species/genera, like mackerel or herring, we ignore the role of food processing and distribution.

The results of this study can be used by policymakers in multisectoral food systems planning. On the consumer end, the food and nutrition sector can use the elasticity estimates when developing programs that harness different fish and seafood species/genera. For example, if developing a nutrition education program aimed toward reducing red meat consumption, dieticians can focus messaging on fish and seafood species/genera that are evidenced as substitutes. On the production end, fisheries managers can incorporate information on consumer demand into their policy decisions and messaging. In the context of the small pelagics fishery closure, fisheries managers can identify to which fish and seafood species/genera might allocate their spending if mackerel and herring supplies decrease.

4.5 Conclusion

Biodiversity is an important factor in influencing food consumption behaviors in settings where diets and nutrition rely on fish and seafood. In this study, we establish variation in consumer demand for fish and seafood species/genera by estimating expenditure elasticities of demand, own-price elasticities, and cross-price elasticities with other protein-rich foods. While we find that, in aggregate, fish and seafood is expenditure and own-price inelastic, there is considerable heterogeneity in estimates when disaggregated into species/genera. Marine forage fish species/genera are generally own-price inelastic, while tuna and shellfish are own-price elastic. Consumers exhibit a mixed hierarchy of preferences for protein-rich foods, in which fish and seafood species/genera are interspersed with animal flesh foods, eggs, and pulses, nuts, and seeds. In next steps, research could use this biodiversity-informed approach on other low- and middle-income contexts where many fish and seafood species/genera are highly consumed or apply this approach to other foods where variation is significant. As this study successfully incorporates biodiversity at the intersection of markets and consumers, food systems research, policy, and practice can use these findings to inform multisectoral interventions where species/genera information is essential.

4.6 References

1. FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome: FAO; 2022.

2. Roos N, Wahab MA, Chamnan C, Thilsted SH. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. J Nutr. 2007;137(4):1106–9.

3. Mitra S, Khatun MostN, Prodhan MdMH, Khan MdA. Consumer preference, willingness to pay, and market price of capture and culture fish: Do their attributes matter? Aquaculture. 2021 Nov;544:737139.

4. Uddin MdT, Rasel MH, Dhar AR, Badiuzzaman Mr, Hoque MdS. Factors Determining Consumer Preferences for Pangas and Tilapia Fish in Bangladesh: Consumers' Perception and Consumption Habit Perspective. Journal of Aquatic Food Product Technology. 2019 Apr 21;28(4):438–49.

5. Bogard JR, Farook S, Marks GC, Waid J, Belton B, Ali M, et al. Higher fish but lower micronutrient intakes: Temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh. PLoS One. 2017;12(4):e0175098.

6. Ministry of Fisheries & Aquaculture Development. National Fisheries Management Plan- A National Policy for the Management of the Marine Fisheries Sector 2015-2019 [Internet]. 2015. Available from: https://www.crc.uri.edu/download/GH2014_POL005_FC_FisheriesMgtPlan2016.pdf

7. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana's evolving protein economy. Food Security. 2016;8(5):909–20.

8. Agyapong N, Annan R, Apprey C, Aryeetey R. A review of Ghana's food system and its implications on sustainability and the development of national food-based dietary guidelines. AJFAND. 2022 Apr 4;22(2):19525–82.

9. Fuseini I. "We Eat Every Day, but I'm Perpetually Hungry": Interrogating Food System Transformation and (Forced) Dietary Changes in Tamale, Ghana. In: Transforming Urban Food Systems in Secodnary Cities in Africa. Cham, Switzerland: Palgrave Macmillan; 2023.

10. Cole JR, McCoskey S. Does global meat consumption follow an environmental Kuznets curve? Sustainability: Science, Practice and Policy. 2013 Oct;9(2):26–36.

11. Vranken L, Avermaete T, Petalios D, Mathijs E. Curbing global meat consumption: Emerging evidence of a second nutrition transition. Environmental Science & Policy. 2014 May;39:95–106.

12. Andam KS, Tschirley D, Asante SB, Al-Hassan RM, Diao X. The transformation of urban food systems in Ghana: Findings from inventories of processed products. Outlook Agric. 2018 Sep;47(3):233–43.

13. Meng T, Florkowski WJ, Sarpong DB, Chinnan MS, Resurreccion AVA, Meng T, et al. Consumer's Food Shopping Choice in Ghana: Supermarket or Traditional Outlets? 2014 [cited 2023 Jun 23]; Available from: https://ageconsearch.umn.edu/record/164600

14. Atta-Mills J, Alder J, Rashid Sumaila U. The decline of a regional fishing nation: The case of Ghana and West Africa. Natural Resources Forum. 2004 Feb;28(1):13–21.

15. Lazar N, Yankson K, Blay J, Ofori-Danson P, Markwei P, Agbogah K, et al. Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018. Report No.: GH2014_SCI042_CRC.

16. Apetorgbor S. Closed Season Brief. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018 p. 10. Report No.: GH2014_POL109_CRC.

17. Owusu V, Adu-Boahen K, Kyeremeh S, Demalie I, Eshun P. Factors influencing compliance of closed fishing season: lessons from small-scale coastal fisheries in the Central Region of Ghana. Humanit Soc Sci Commun. 2023 Jan 17;10(1):20.

18. Ministry of Food and Agriculture, Fisheries Commission. Ghana National Aquaculture Development Plan (GNADP) [Internet]. Accra, Ghana: Ministry of Food and Agriculture; 2012. Available from: https://faolex.fao.org/docs/pdf/gha149443.pdf

19. Ragasa C, Andam KS, Asante SB, Amewu S. Can local products compete against imports in West Africa? Supply- and demand-side perspectives on chicken, rice, and tilapia in Ghana. Global Food Security. 2020;26.

20. Ragasa C, Agyakwah SK, Asmah R, Mensah ETD, Amewu S, Oyih M. Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana. Aquaculture. 2022 Jan;547:737476.

21. Dey MM, Alam MdF, Paraguas FJ. A Multistage Budgeting Approach to the Analysis of Demand for Fish: An Application to Inland Areas of Bangladesh. Marine Resource Economics. 2011 Mar;26(1):35–58.

22. Onumah EE, Quaye EA, Ahwireng AK, Campion BB. Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. Sustainability. 2020;12(19):7932.

23. Ackah C, Appleton S. Food price changes and consumer welfare in Ghana in the 1990s [Internet]. CREDIT Research Paper. Nottingham: University of Nottingham, Centre for Research in Economic Development and International Trade; 2007. Available from: http://hdl.handle.net/10419/80310

24. Akpalu W, Okyere MA. Fish Protein Transition in a Coastal Developing Country. Environ Resource Econ. 2023 Mar;84(3):825–43.

25. Akuffo A S, Quagrainie KK, Obirikorang KA. Analysis of the determinants of fish consumption by households in Ghana. Aquaculture Economics & Management. 2020;24(3).

26. Ansah IGK, Marfo E, Donkoh SA. Food demand characteristics in Ghana: An application of the quadratic almost ideal demand systems. Scientific African. 2020;8:e00293.

27. McNamara J, Fa JE, Ntiamoa-Baidu Y. Understanding drivers of urban bushmeat demand in a Ghanaian market. Biological Conservation. 2019 Nov;239:108291.

28. Osei-Asare YB, Eghan M. Food price inflation and consumer welfare in Ghana. international Journal of Food and Agricultural Economics. 2013;1(1):27–39.

29. Kotchofa P. To what extent do household expenditure and prices affect the demand for rice in northern Ghana? 2018 [cited 2023 Jun 24]; Available from: https://ageconsearch.umn.edu/record/266570

30. Roos N, Leth T, Jakobsen J, Thilsted SH. High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency. International Journal of Food Sciences and Nutrition. 2002 Jan;53(5):425–37.

31. Dey MM, Garcia YT, Praduman K, Piumsombun S, Haque MS, Li L, et al. Demand for fish in Asia: a cross-country analysis*. Australian Journal of Agricultural and Resource Economics. 2008;52(3):321–38.

32. Chikowi CTM, Ochieng DO, LJumbe CB. Consumer choices and demand for tilapia in urban Malawi: What are the complementarities and trade-offs? Lilongwe, Malawi: IFPRI-Malawi; 2019.

33. Lancker K, Bronnmann J. Substitution Preferences for Fish in Senegal. Environ Resource Econ. 2022 Aug;82(4):1015–45.

34. Owusu AA, Ankrah MY, Boateng GP, Anteh G. Food Weights/Handy Measures Tables (Ghana). Ghana: Dietetic Group of the Dreyfus Health Foundation; 1995.

35. Deaton A, Muellbauer J. An Almost Ideal Demand System. The American Economic Review. 1980;70(3):15.

36. Banks J, Blundell R, Lewbel A. Quadratic Engel Curves and Consumer Demand. The Review of Economics and Statistics. 1997;79(4):13.

37. Dey MM. Analysis of demand for fish in Bangladesh. Aquaculture Economics & Management. 2000 Nov;4(1–2):63–81.

38. Garcia YT, Mohan Dey M, Navarez SMM. DEMAND FOR FISH IN THE PHILIPPINES: A DISAGGREGATED ANALYSIS. Aquaculture Economics & Management. 2005 Jan;9(1–2):141–68.

39. Shonkwiler JS, Yen ST. Two-Step Estimation of a Censored System of Equations. American Journal of Agricultural Economics. 1999 Nov;81(4):972–82.

40. Caro JC, Melo G, Molina JA, Salgado JC. Censored QUAIDS estimation with quaidsce* [Internet]. Boston: Boston College; 2021. Available from: http://fmwww.bc.edu/EC-P/wp1045.pdf

41. Poi BP. Easy demand-system estimation with quaids. The Stata Journal. 2012;12(3).

42. Clements KW, Si J. Price Elasticities of Food Demand: Compensated vs Uncompensated. Health Econ. 2016;25(11):1403–8.

43. Ashitey E. Fish and Seafood report [Internet]. USDA Foreign Agricultural Service, Global Agricultural Information Network; 2019. (GAIN Report). Available from: https://agriexchange.apeda.gov.in/MarketReport/Reports/Fish_and_Seafood_Report_Accra_Ghana_3-8-2019.pdf

44. Unimer Group. Unimer group - Unimer [Internet]. 2020. Available from: https://unimergroup.com/

45. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana’s evolving protein economy. Food Security. 2016;8(5):909–20.

46. Gyampoh B, Atitsogbui G, Obirikorang K. Understanding the neglected shellfish fishery of the Keta Lagoon, Ghana. J Fish Coast Mgt. 2020;2(1):1.

47. Hayford A. Consumers’ Attitude towards Oyster Consumption in Ghana. In: Sheu DrGY, editor. New Ideas Concerning Science and Technology Vol 9 [Internet]. Book Publisher International (a part of SCIENCEDOMAIN International); 2021 [cited 2023 Jul 15]. p. 48–61. Available from: https://stm.bookpi.org/NICST-V9/article/view/500

48. Afetsu JY, Kumah MS. An Assessment of Acceptance of Snails as Food in the Tamale Metropolis of the Northern Region - Ghana. Researchjournali’s Journal of Agriculture. 2016;3(6).

49. O’Neill ED, Asare N, Aheto D. Socioeconomic dynamics of the Ghanaian tuna industry: a value-chain approach to understanding aspects of global fisheries. African Journal of Marine Science. 2018 Jul 3;40(3):303–13.

50. Kwakye-Opong R. Clothing and Colour Symbolisms in the Homowo Festival: A means to Sociocultural Development. Research on Humanities and Social Sciences. 2014;4(13):112–25.

51. Rich KM, Wane A. The Competitiveness of Beef Exports From Burkina Faso to Ghana. Front Vet Sci. 2021 Aug 6;8:619044.

52. Osman A, Karikari PK, Osafo ELK, Attoh-Kotoku V. Smallholder urban cattle production: prospects and challenges in the Kumasi Metropolis and Asokore Mampong Municipality of the Ashanti Region of Ghana. Ghanaian Journal of Animal Science. 2018;9(2).

53. Ministry of Food and Agriculture and University of Ghana School of Public Health. Food-Based Dietary Guidelines [Internet]. 2023. Available from: https://mofa.gov.gh/site/images/pdf/Ghana_Food_Based_Dietary_Guidelines_2023.pdf

54. Kusi LY, Agbeblewu S, Anim IK, Nyarku KM. The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature. International Journal of Management Sciences. 2015;5(6):476–89.

55. Dallmann D, Marquis GS, Colecraft EK, Kanlisi R, Aidam BA. Maternal Participation Level in a Nutrition-Sensitive Agriculture Intervention Matters for Child Diet and Growth Outcomes in Rural Ghana. Current Developments in Nutrition. 2022 Mar;6(3):nzac017.

56. Nsabimana A, Bali Swain R, Surry Y, Ngabitsinze JC. Income and food Engel curves in Rwanda: a household microdata analysis. Agric Econ. 2020 Dec;8(1):11.

4.7 Tables and figures

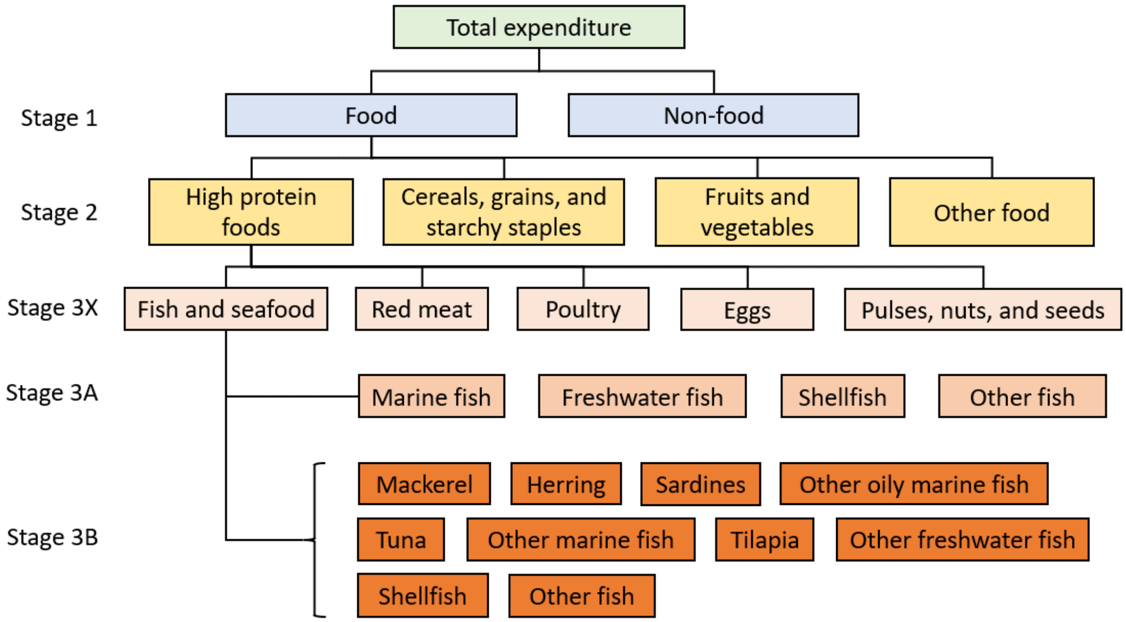

Figure 4.1: Three stage budgeting framework for fish and seafood and other protein-rich foods.

Table 4.1: Fish and seafood species/genera groups, composition, and weighted average price.

Species/genera group	Species/genera composition; English and local Ghanaian and/or brand names (scientific name)	Weighted average price (Cedi/kg)
Mackerel	• West African Atlantic mackerel; salmon, samaa, saforo (*Scomberomorus tritor*) • Mackerel in tomato sauce; African Queen, Geisha, Gino, Ena Pa, Obaapa, Delay, Teacher, other brands	6.83
Herring	• Long fin herring; amani, Keta school boys (*Ilisha africana*)	2.82
Sardines	• Canned sardines; Titus, Princess, Obaapa, Gino, Smile, Lele, Vega, other brands	12.63
Tuna	• Frigate tuna; opoku (*Auxis thazard*) • Tuna in vegetable oil; Starkist, Vega, Geisha, Tesco, John West, other brands	4.54
Other oily marine fish	• Anchovy; abobi, nsesaawa (*Anchoa guineensis*) • Sardine; amane (*Sardinella spp.)* • Atlantic horse mackerel; kpanla (*Trachurus trachurus*) • African jack mackerel (*Caranx hippos*)	3.07
Other marine fish	• Bumper; antele (*Chloroscombus chrysurus*) • Cassava fish (*Pseudotolitus senegalensis*) • Red porgy; red fish, cheele (*Pagrus pagrus*) • Monrovia doctor fish (*Acanthurus monroviae*) • False scad; emule (*Caranx rhonchus*) • Barracuda; odue (*Sphraeyna spp.*) • Sharks, rays, or skates, kako (*Elasmobranchii*)	3.79
Tilapia	• Tilapia; kwabi, koobi (*Oreochromis niloticus*)	3.56
Other freshwater fish	• Catfish; gblolovi (*Chrysichthys spp.*) • Catfish; adwene (*Clarias spp*., *Heterobranchus spp*.) • West African pigmy herring; one man thousand (*Sierathrissia spp.*)	4.77
Shellfish	• Blue crab (*Callinectes sepidus*) • Shrimp (*Crago septemspinosus*) • Lobster (*Panilirus regius*) • Oyster; adode (*Crassostrea tulipa*) • Snail (*Achatina spp.*, *Archachatina marginata*)	2.15
Other fish and seafood	GLSS 7 food list items include smoked fish (river), smoked fish (sea), fried fish, and unidentifiable ‘other fish’ write-in responses	1.92
Red and other meat	GLSS 7 food list items include cow/beef, pork, mutton, goat, corned beef, sausage, grasscutter, and other meat	1.84
Poultry	GLSS 7 food list items include chicken, guinea fowl, and game birds	3.21
Eggs	GLSS 7 food list items include chicken and other eggs	1.84
Pulses, nuts, and seeds	GLSS 7 food list items include white beans (cowpeas), groundnuts, and agushie seeds	2.35

Table 4.2. Consumption and expenditure patterns of fish and seafood and other protein-rich foods by income quartiles and rural/urban status.

	Income quartile					
Food group	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**	**Rural**	**Urban**
Monthly consumption per adult equivalent by income groups and rural/urban status (kg)						
Mackerel	0.04	0.16	0.31	0.54	0.20	0.36
Herring	0.41	0.42	0.43	0.48	0.52	0.33
Sardines	0.00	0.00	0.01	0.02	0.00	0.01
Tuna	0.00	0.00	0.00	0.01	0.00	0.01
Other oily marine fish	0.05	0.09	0.13	0.20	0.11	0.13
Other marine fish	0.04	0.17	0.28	0.40	0.19	0.27
Tilapia	0.02	0.04	0.07	0.10	0.06	0.06
Other freshwater fish	0.09	0.19	0.22	0.25	0.21	0.16
Shellfish	0.00	0.01	0.03	0.07	0.01	0.05
Other fish and seafood	0.06	0.17	0.25	0.38	0.19	0.25

Total fish and seafood	0.73	1.26	1.73	2.46	1.49	1.62
Red and other meat	0.25	0.47	0.53	1.06	0.36	0.87
Poultry	0.07	0.16	0.31	0.61	0.22	0.37
Eggs	0.02	0.08	0.17	0.54	0.10	0.34
Pulses, nuts, and seeds	0.11	0.17	0.20	0.25	0.19	0.18
Monthly expenditure share (proportion of total protein-rich food expenditure)						
Mackerel	0.07	0.14	0.18	0.19	0.19	0.11
Herring	0.40	0.18	0.12	0.07	0.10	0.27
Sardines	0.00	0.01	0.02	0.05	0.03	0.01
Tuna	0.00	0.00	0.00	0.01	0.00	0.00
Other oily marine fish	0.07	0.05	0.04	0.03	0.04	0.06
Other marine fish	0.05	0.12	0.12	0.10	0.11	0.09
Tilapia	0.02	0.02	0.03	0.03	0.03	0.02
Other freshwater fish	0.12	0.12	0.10	0.07	0.08	0.13
Shellfish	0.00	0.00	0.00	0.01	0.01	0.00
Other fish and seafood	0.04	0.05	0.06	0.06	0.06	0.05
Total fish and seafood	0.78	0.71	0.67	0.62	0.64	0.73
Red and other meat	0.09	0.12	0.14	0.15	0.15	0.10
Poultry	0.05	0.07	0.09	0.10	0.09	0.07
Eggs	0.02	0.04	0.06	0.09	0.08	0.03
Pulses, nuts, and seeds	0.07	0.06	0.04	0.03	0.04	0.06

Table 4.3. Parameter estimates of the food expenditure function.

Variable	Estimate	Standard error
Intercept	0.570***	0.050
ln SPI of food	0.111***	0.003
ln per capita expenditure	0.742***	0.019
(ln per capita expenditure)^2	0.028***	0.002
ln non-food expenditure	-0.001***	0.000
Household size	0.005***	0.001
Rural status	0.038***	0.006
Region (referent: Accra)		
Western	0.155***	0.012
Central	0.197***	0.012
Volta	0.110***	0.012
Eastern	0.167***	0.012
Ashanti	0.054***	0.011
Brong Ahafo	0.095***	0.012
Northern	-0.039**	0.013
Upper East	0.029*	0.013
Upper West	0.008	0.013
Survey quarter (referent: January-March)		
April-June	0.009	0.007
July-September	-0.002	0.007
October-December	0.005	0.007
Adjusted R^2	0.9037	
F-value	<0.001	

*** $P \leq 0.001$
** $P \leq 0.01$
* $P \leq 0.05$

Table 4.4. Parameter estimates of the protein-rich food expenditure function.

Variable	Estimate	Standard error
Intercept	0.600	0.123
ln price of protein-rich foods	0.017	0.014
ln price of cereals, grains, and starchy staples	-0.029***	0.007
ln price of fruits and vegetables	-0.050***	0.013
ln price of other foods	0.022*	0.010
ln food expenditure	-1.374***	0.147
$(\ln \text{food expenditure})^2$	1.912***	0.055
Household size	0.018***	0.003
Rural status	0.124***	0.013
Region (referent: Accra)		
Western	0.233***	0.027
Central	0.107***	0.026
Volta	0.207***	0.026
Eastern	0.164***	0.025
Ashanti	0.147***	0.024
Brong Ahafo	0.275***	0.026
Northern	-0.205***	0.027
Upper East	-0.076*	0.030
Upper West	-0.287***	0.030
Survey quarter (referent: January-March)		
April-June	0.055***	0.016
July-September	0.112***	0.014
October-December	0.003	0.015
Adjusted R^2	0.6917	
F-value	<0.001	

*** $P \leq 0.001$
** $P \leq 0.01$
* $P \leq 0.05$

Table 4.5. Estimated expenditure elasticities for protein-rich foods.

	Expenditure elasticity	**Standard error**
*Stage 2: protein-rich foods**	1.63	0.04
Stage 3: protein-rich food groups		
Fish and seafood	0.90	0.01
Red and other meat	1.26	0.01
Poultry	1.03	0.01
Eggs	1.59	0.04
Pulses, nuts, and seeds	1.10	0.06
Stage 3A: protein-rich foods, fish and seafood groups		
Marine fish	1.00	<0.01
Freshwater fish	1.01	0.01
Shellfish	0.65	0.45
Other fish and seafood	1.22	0.02
Red and other meat	1.08	0.01
Poultry	1.10	0.01
Eggs	1.28	0.02
Pulses, nuts, and seeds	0.99	0.02
Stage 3B: protein-rich foods, fish and seafood species/genera		
Mackerel	1.05	0.01
Herring	1.01	0.01
Sardines	0.61	0.04
Tuna	1.12	0.10
Small oily marine fish	1.02	0.02
Other marine fish	1.01	0.01
Tilapia	1.00	0.04
Other freshwater fish	0.94	0.01
Shellfish	1.08	0.05
Other fish and seafood	1.07	0.02
Red and other meat	1.18	0.01
Poultry	1.13	0.02
Eggs	1.22	0.04
Nuts, seeds, and pulses	1.09	0.03

* With respect to food expenditure

Table 4.6. Own-price elasticities of protein-rich foods and fish and seafood.

	Uncompensated own-price elasticity	**Standard error**	**Compensated own-price elasticity**	**Standard error**
Stage 2: protein-rich foods	-0.76	<0.01	-0.58	0.03
Stage 3: protein-rich food groups				
Fish and seafood	-1.14	0.01	-0.40	0.02
Red and other meat	-1.07	0.01	-0.91	0.01
Poultry	-1.03	0.01	-0.92	0.01
Eggs	-1.09	0.05	-1.05	0.05
Pulses, nuts, and seeds	-0.93	0.08	-0.92	0.08
Stage 3A: protein-rich foods, fish and seafood groups				
Marine fish	-1.00	<0.01	-0.47	<0.01
Freshwater fish	-1.03	<0.01	-0.85	<0.01
Shellfish	-1.20	0.10	-1.20	0.10
Other fish and seafood	-1.01	<0.01	-0.95	0.01
Red and other meat	-1.06	<0.01	-0.94	<0.01
Poultry	-0.99	0.01	-0.91	0.01
Eggs	-1.10	0.01	-1.06	0.01
Pulses, nuts, and seeds	-1.01	0.01	-0.96	0.01
Stage 3B: protein-rich foods, fish and seafood species/genera				
Mackerel	-0.92	<0.01	-0.75	<0.01
Herring	-1.01	<0.01	-0.81	<0.01
Sardines	-0.83	0.02	-0.81	0.02
Tuna	-1.57	0.04	-1.56	0.04
Small oily marine fish	-0.97	0.01	-0.92	0.01
Other marine fish	-0.95	<0.01	-0.86	<0.01
Tilapia	-0.97	0.02	-0.93	0.02
Other freshwater fish	-0.99	<0.01	-0.87	<0.01
Shellfish	-1.28	0.02	-1.30	0.02
Other fish and seafood	-1.02	0.01	-0.97	0.01
Red and other meat	-1.04	0.01	-0.94	0.01
Poultry	-0.98	0.01	-0.89	0.01
Eggs	-1.10	0.01	-1.06	0.01
Pulses, nuts, and seeds	-1.04	0.01	-0.99	0.01

Table 4.7. Compensated price elasticities for Stage 3: protein-rich foods.

	Compensated cross-price elasticities (estimate, SE)				
	Fish and seafood	Red and other meat	Poultry	Eggs	Pulses, nuts, and seeds
Fish and seafood	-0.40 (0.02)	0.09 (0.01)	0.09 (0.01)	0.02 (0.02)	0.03 (0.01)
Red and other meat	1.28 (0.02)	-0.91 (0.01)	0.18 (0.01)	0.08 (0.01)	0.00 (0.01)
Poultry	0.96 (0.01)	0.19 (0.01)	-0.92 (0.01	-0.01 (0.01)	0.02 (0.01)
Eggs	2.39 (0.07)	0.26 (0.04)	0.10 (0.03)	-1.05 (0.05)	-0.16 (0.03)
Pulses, nuts, and seeds	1.16 (0.10)	-0.04 (0.07)	0.13 (0.06)	-0.28 (0.07)	-0.92 (0.08)

Table 4.8. Compensated price elasticities for Stage 3A: protein-rich and fish and seafood groups.

	Compensated cross-price elasticities (estimate, SE)							
	Marine fish	Freshwater fish	Shellfish	Other fish and seafood	Red and other meat	Poultry	Eggs	Pulses, nuts, and seeds
Marine fish	-0.47 (<0.01)	0.19 (<0.01)	0.01 (<0.01)	0.06 (<0.01)	0.11 (<0.01)	0.07 (<0.01)	0.05 (<0.01)	0.05 (<0.01)
Freshwater fish	0.57 (<0.01)	-0.85 (<0.01)	-0.01 (<0.01)	0.04 (<0.01)	0.11 (<0.01)	0.09 (<0.01)	0.02 (<0.01)	0.07 (<0.01)
Shellfish	1.98 (0.15)	-0.66 (0.12)	-1.20 (0.10)	0.74 (0.10)	0.09 (0.10)	-0.54 (0.09)	-0.12 (0.012)	0.65 (0.09)
Other F&S	0.62 (0.01)	0.15 (0.01)	0.02 (<0.01)	-0.95 (0.01)	0.09 (<0.01)	0.11 (<0.01)	0.05 (0.01)	0.03 (<0.01)
Red/other meat	0.64 (0.01)	0.20 (<0.01)	0.00 (<0.01)	0.04 (<0.01)	-0.94 (<0.01)	0.09 (<0.01)	0.06 (<0.01)	0.08 (<0.01)
Poultry	0.59 (0.01)	0.22 (0.01)	-0.02 (<0.01)	0.06 (0.01)	0.14 (<0.01)	-0.91 (0.01)	0.06 (0.01)	0.04 (<0.01)
Eggs	0.87 (0.01)	0.15 (0.01)	0.00 (0.01)	0.08 (0.01)	0.15 (0.01)	0.16 (0.01)	-1.06 (0.01)	0.03 (0.01)
Pulses/nuts/seeds	0.53 (0.01)	0.25 (0.01)	0.03 (<0.01)	0.03 (<0.01)	0.15 (0.01)	0.04 (<0.01)	0.02 (<0.01)	-0.96 (0.01)

Table 4.9: Compensated price elasticities for Stage 3B: protein-rich foods and fish and seafood species/genera.

	Compensated cross-price elasticities (estimate, SE)									
	Mackerel	Herring	Sardines	Tuna	Small oily marine fish	Other marine fish	Tilapia	Other freshwater fish	Shellfish	Other fish and seafood
Mackerel	-0.75 (<0.01)	0.21 (<0.01)	-0.02 (<0.01)	0.01 (<0.01)	0.04 (<0.01)	0.11 (<0.01)	0.05 (<0.01)	0.11 (<0.01)	-0.06 (<0.01)	0.02 (<0.01)
Herring	0.15 (<0.01)	-0.81 (<0.01)	0.00 (<0.01)	0.02 (<0.01)	0.06 (<0.01)	0.08 (<0.01)	0.04 (<0.01)	0.12 (<0.01)	0.00 (<0.01)	0.06 (<0.01)
Sardines	-0.16 (0.02)	-0.07 (0.01)	-0.81 (0.020	0.07 (0.02)	0.03 (0.01)	-0.09 (0.01)	0.06 (0.01)	0.14 (0.01)	0.05 (0.01)	0.16 (0.01)
Tuna	0.15 (0.04)	0.55 (0.02)	0.15 (0.03)	-1.56 (0.04)	0.26 (0.03)	0.27 (0.03)	-0.17 (0.03)	0.15 (0.03)	0.11 (0.02)	0.24 (0.02)
S. oily mar. fish	0.14 (0.01)	0.24 (0.01)	0.06 (0.01)	0.03 (0.01)	-0.92 (0.01)	0.12 (0.01)	-0.02 (0.01)	0.13 (0.01)	-0.02 (<0.01)	0.03 (<0.01)
Oth. Mar. fish	0.18 (<0.01)	0.18 (<0.01)	-0.03 (<0.01)	0.03 (<0.01)	0.07 (<0.01)	-0.86 (<0.01)	0.04 (<0.01)	0.15 (<0.01)	-0.01 (<0.01)	0.04 (<0.01)
Tilapia	0.24 (0.03)	0.23 (0.02)	0.05 (0.02)	-0.04 (0.03)	-0.01 (0.02)	0.09 (0.02)	-0.93 (0.02)	0.11 (0.02)	-0.04 (0.01)	0.03 (0.02)
Oth. frshw. fish	0.13 (<0.01)	0.19 (<0.01)	0.04 (<0.01)	0.01 (<0.01)	0.04 (<0.01)	0.11 (<0.01)	0.03 (<0.01)	-0.87 (<0.01)	-0.03 (<0.01)	0.04 (<0.01)
Shellfish	0.53 (0.02)	0.05 (0.01)	-0.07 (0.02)	-0.03 (0.02)	0.04 (0.01)	0.05 (0.01)	0.11 (0.01)	0.18 (0.02)	-1.30 (0.02)	-0.02 (0.01)
Other F&S	0.11 (0.01)	0.27 (0.01)	0.10 (0.01)	0.07 (0.01)	0.05 (0.01)	0.07 (0.01)	0.00 (0.01)	0.12 (0.01)	-0.01 (0.01)	-0.97 (0.01)
Red/oth. meat	0.22 (0.01)	0.23 (0.01)	0.08 (0.01)	-0.07 (0.01)	0.04 (0.01)	0.07 (0.01)	0.19 (0.01)	0.14 (0.01)	0.04 (0.02)	0.08 (0.01)
Poultry	0.23 (0.01)	0.18 (0.01)	0.06 (0.01)	0.01 (0.01)	0.02 (0.01)	0.08 (0.01)	0.04 (0.01)	0.13 (0.01)	-0.01 (<0.01)	0.03 (0.01)
Eggs	0.11 (0.02)	0.27 (0.01)	0.16 (0.01)	0.02 (0.02)	0.12 (0.01)	0.12 (0.01)	0.08 (0.01)	0.23 (0.01)	-0.06 (0.01)	0.16 (0.01)
P, N, & S	0.17 (0.01)	0.18 (0.01)	0.09 (0.01)	0.02 (0.01)	0.05 (0.01)	0.06 (0.01)	0.05 (0.01)	0.13 (0.01)	-0.01 (0.01)	0.06 (0.01)

	Red and other meat	Poultry	Eggs	Pulses, nuts, and seeds
Mackerel	0.09 (<0.01)	0.10 (<0.01)	0.01 (<0.01)	0.04 (<0.01)
Herring	0.08 (<0.01)	0.06 (<0.01)	0.04 (<0.01)	0.04 (<0.01)
Sardines	0.18 (0.01)	0.06 (0.01)	0.08 (0.01)	0.10 (0.01)
Tuna	-0.33 (0.02)	0.07 (0.02)	0.08 (0.03)	0.10 (0.02)
S. oily mar. fish	0.07 (0.01)	0.05 (0.01)	0.05 (0.01)	0.04 (<0.01)
Oth. Mar. fish	0.05 (<0.01)	0.06 (<0.01)	0.03 (<0.01)	0.02 (<0.01)
Tilapia	0.19 (0.01)	0.14 (0.01)	0.04 (0.02)	0.08 (0.01)
Oth. frshw. fish	0.09 (<0.01)	0.07 (<0.01)	0.05 (<0.01)	0.04 (<0.01)
Shellfish	0.15 (0.01)	0.07 (0.01)	0.07 (0.01)	0.02 (0.01)
Other F&S	0.07 (0.01)	0.06 (0.01)	0.06 (0.01)	0.04 (<0.01)
Red/oth. meat	-0.94 (0.01)	0.14 (<0.01)	0.03 (<0.01)	0.10 (<0.01)
Poultry	0.17 (<0.01)	-0.89 (0.01)	0.02 (<0.01)	0.06 (<0.01)
Eggs	0.10 (0.01)	0.06 (0.01)	-1.06 (0.01)	-0.09 (0.01)
P, N, & S	0.18 (0.01)	0.10 (0.01)	-0.06 (0.01)	-0.99 (0.01)

Chapter 5 Conclusion

5.1 Summary of dissertation findings

Food systems in low- and middle-income countries are rapidly transforming (1,2) due to population growth, urbanization, rising consumer incomes, and changes to the natural and built environment (3). In these contexts, food systems transformation is associated with a range of malnutrition outcomes (4), including the triple burden of malnutrition, or concurrent undernourishment, micronutrient deficiencies, and overnutrition (5–8). To alleviate these public health issues, food systems will need to enact multisectoral policies and interventions that are appropriate for a range of nutrition goals (1). Fish and seafood is a set of nutrient dense animal source foods that comprise healthy diets in a variety of nutrition environments. In food systems that heavily rely on fisheries and aquaculture, its population may consume a variety of fish and seafood species/genera (i.e., biodiversity). Thus, the overall aim of this dissertation was to assess fish and seafood biodiversity in the food system and nutrition linkages in Ghana and characterize its influence on consumer behaviors. To accomplish this, we analyzed primary interview data that we collected in July and August 2019 from fish and seafood producers, processors, distributors and consumers in Accra, Ghana and cross-sectional household consumption expenditure data collected in 2016-17 from the seventh round of the Ghana Living Standards Survey.

In Chapter 2, we used qualitative research methods to identify a range of fish and seafood consumer behaviors and their linkages to the surrounding food system of Accra, Ghana. From this analysis, we interpolated four interrelated themes ('tastes and preferences', 'health and nutrition', 'social, cultural, and religious factors', and 'cost and convenience') that influence the linkages we identified between fish and seafood consumption and food systems components. We found that the interviewee sample consumed 22 distinct fish and seafood species/genera. Interviewees indicated their preferences to eat mackerel, herring, tuna, and tilapia in traditional soups and stews with minimally processed starchy staples, such as *banku* or *kenkey*. In general, oily marine fish (mackerel and herring) that originate from the overfished small pelagics fishery were consumed frequently and regarded as beneficial to health and nutrition. Larger marine species (tuna, redfish, and barracuda) were highly valued but consumed infrequently for special occasions. Tuna and tilapia were consumed in restaurants and bars, which often drew concerns over lack of food safety. Consumers reported that fish and seafood prices constrained their varying preferences specific species/genera. Nearly all interviewees prioritized fish and seafood in comparison with other animal source foods (red meat, poultry, eggs, and nuts, seeds, and pulses).

To explore these consumer behaviors in a national population, in Chapter 3, we identified the dominant patterns of food expenditure in Ghana and assessed their correlations with fish and seafood species/genera. We found three patterns of food expenditure that aligned with different patterns of the nutrition transition (9). Household expenditures on freshwater fish species/genera were correlated with starchy staples and fruits and vegetables (e.g., our 'Traditional' pattern with Popkin's famine nutrition transition pattern), as opposed to marine fish species/genera that were correlated with refined grains and cereal products, dairy, and sweets (e.g., our 'Processed foods' pattern loosely aligned the Degenerative diseases pattern). No fish and seafood were correlated in the pattern that comprised food away from home (e.g., also matched with the Degenerative diseases pattern).

Then, we used multivariable regression analysis to examine statistical associations between food expenditure patterns and sociodemographic, economic, and environmental factors. We found that the associations were largely demarcated by socioeconomic status. For example, households adhering to the 'Traditional' pattern were positively associated with head of household age, female head of household status, and lower educational attainment. The 'FAFH' pattern was associated with younger heads of households, male heads households, and urban residence. The 'Processed foods' pattern exhibited mixed associations with socioeconomic variables, thus, potentially describes households undergoing socioeconomic transition.

In Chapter 4, we explored the consumer demand for 10 fish and seafood species/genera in Ghana. We estimated that fish and seafood represent 23.4% of total food spending and 69.7% of protein-rich food expenditures. However, we observed heterogeneity in household expenditures by species/genera: for example, herring was highly consumed in lower income quartiles, but mackerel was consumed in higher income quartiles. To estimate consumer responses to income and price, we specified a censored Quadratic Almost Ideal Demand System model that analyzed cross-sectional household consumption expenditure data from the GLSS 7. We found that tuna and shellfish had higher expenditure elasticities than mackerel, herring, and sardines. Fish and seafood was own-price inelastic, though disaggregating by species/genera revealed that tuna and shellfish were own-price elastic. Finally, in comparing the cross-price elasticities of demand, we show heterogeneous consumer preferences for fish and seafood species/genera that are interspersed with other protein-rich foods.

5.2 Biodiversity as roadmap to food system-nutrition linkages

The three studies conducted in this dissertation provide a research framework for using biodiversity to describe food systems linkages with food consumption and nutrition.

In the qualitative study (Chapter 2), we found two prevailing fish and seafood consumption behaviors that occurred across socioeconomic levels. The first is that interviewees reported consuming a mix of fish and seafood species/genera from marine and freshwater production sources in vegetable stews served with starchy staples. However, this finding was only partially supported in the epidemiologic research described in Chapter 3. For example, the food expenditure pattern of tilapia and other freshwater fish with fruits, vegetables, and starchy staples aligns with the traditional dishes described in the qualitative interviews. On the other hand, the food expenditure pattern of anchovy and sardines with refined grains, dairy, and snacks contradicts our findings, as no interviewee described consuming these foods with fish and seafood. There are a few potential reasons for the discrepancies in our results. One is a conceptual misalignment in the data collected, as the qualitative interviews asked interviewees to report how they perceive their behaviors, while the GLSS 7 collected household food expenditures via food diaries and recall. Another is the difference in analytic approaches, as we can potentially observe the limited generalizability of our qualitative themes and patterns against national level statistics. Finally, the qualitative research found interviewees consuming fish and seafood as part of traditional dishes, which we understand as fish and seafood, vegetables, and starchy staples are cooked and consumed together; the food expenditure patterns only represent correlations in what households purchase over the course of one month.

From the qualitative results, we interpret the lack of trends between species/genera and socioeconomic status as indicative of the general role that fish and seafood plays in healthy diets. In Chapter 3, we found that certain species/genera were correlated in distinct food expenditure patterns, which could impact the diet quality and nutrition outcomes of highly adherent households. Since whole sardines and anchovy contain much more calcium, iron, zinc, and vitamin A, than tilapia and catfish fillets, our results portend that households adhering to the 'Traditional' food expenditure pattern have lower micronutrient intake than households adhering to the 'Processed foods' pattern. Bogard et al. (2017) evidenced this trend in Bangladesh, finding that higher farmed fish consumption was associated with lower micronutrient intake (10). This lower micronutrient intake is especially concerning for maternal and child nutrition, as the 'Traditional' pattern is associated household pregnancy and children aged under 5y. To address the micronutrient deficiencies angle of the triple burden of malnutrition, Ghana's food-based dietary recommendations could specify oily marine fish as micronutrient dense, in addition to their current messaging regarding protein intake and cardiovascular disease risk.

A second consumer behavior that emerged from the qualitative study was a strong preference for fish and seafood over other animal source foods. When prompted, interviewees said their first response to higher fish and seafood prices would be to buy less of their preferred species/genera, then substitute less desirable species/genera, or switch to other protein-rich foods, such as red meat, poultry, eggs, or legumes, as a last resort. This behavior was generally supported in the empirical research in Chapter 4, although a more complex hierarchy of preferences emerged. In comparing the price elasticities of demand for mackerel and herring, two highly consumed species/genera, we observed that consumers were less responsive to their own-price changes than for red and other meat, poultry, eggs, and pulses, nuts, and seeds. We also observed that the most preferred substitutes for mackerel and herring, as indicated by their cross-price elasticity estimates, were other species/genera, shellfish and tuna, respectively. While other species/genera were substitutes to a lesser degree, we found that their cross-price elasticity estimates were on par with or less than other protein-rich foods. For mackerel, the cross-price elasticity estimates for tilapia and red and other meat were of similar magnitudes, but both were higher than the estimates for herring and other small oily marine fish. This order of cross-price elasticity estimates suggests that consumer preferences conflict with nutrition praxis. In Ghana's recently released dietary guidelines, consumption of oily marine fish is promoted over other animal source foods that are high in saturated fat content (11). Moreover, consumers substituting tilapia over small oily marine fish for mackerel could lead to reduced omega-3 polyunsaturated fatty acid and micronutrient intake, as we postulated in light of the epidemiologic results.

5.3 Dissertation strengths and limitations

This dissertation strengthens the research discourse on food systems and nutrition in several ways. First, this dissertation builds on prior research that assesses linkages between agrobiodiversity and diets (12) by building biodiversity into multidisciplinary food systems modeling. We harness foundational approaches for which there is existing literature (qualitative research on food systems, diet pattern analysis, and demand system modeling) to show the informational value that incorporating biodiversity brings. Past food systems research tends to focus on terrestrial biodiversity (12), such as crop species, while ignoring aquatic ecosystems. We help fill that gap with research focusing on marine and freshwater species/genera produced by both wild capture and aquaculture. Another strength pertains to the research we conducted in Chapters 3 and 4. Other studies of food consumption patterns analyze data from smaller samples defined by life stage, income, or administrative region, thereby limiting generalizability. In

Chapter 3, we analyzed the seventh round of the Ghana Living Standards Survey, a national dataset collected by the Ghana Statistical Service, that enabled us to assess patterns on a national scale while accounting for those sociodemographic, economic, and environmental factors. With regards to Chapter 4, while other studies of food demand and Ghana use previous rounds of the GLSS, we analyze the most recent survey round (GLSS 7) and incorporate two methodological features (nonlinear relationships between income and food budget allocations and zero food expenditures) that address persistent research challenges.

This dissertation experiences limitations in design and scope. In Chapter 2, our small sample size and focus on Accra impedes generalizing the themes and patterns we identified to different populations. Despite this, the findings from Chapter 2 were immensely useful in generating hypotheses that we could test on a national scale in subsequent work. The empirical research in Chapters 3 and 4 are limited by the cross-sectional data they analyzed. Therefore, we cannot establish causality between trends and outcomes, such as food price changes and consumer responses. Finally, our research objective to focus on biodiversity impairs understanding other food systems factors that influence fish and seafood consumption. One important example is food processing, for which the GLSS 7 considered for some but not all food items.

5.4 Future research

Our research presents new avenues for future research on food systems, biodiversity, and fish and seafood consumption. In Chapter 3, we establish the dominant patterns of household food expenditure at the national level in Ghana. Lachat et al. (2018), found that dietary species richness performs well in identifying nutrient adequate diets (13). However, since our analyses focused on food expenditure, not food consumption, we cannot draw inferences on whether fish and seafood biodiversity matters for nutrient intake. Future research could analyze the food consumption data in the GLSS 7 to estimate household nutrient supplies. These studies could also use optimizing methods, such as linear programming analysis (14), to assess which fish and seafood species/genera contribute most to adequate nutrient intakes. They could also incorporate food price data to add constraints around costs and affordability (15).

Another line of research pertains to ongoing policy initiatives in Ghana, the scale up of tilapia aquaculture in Lake Volta, and the import ban on tilapia (16,17), and the small pelagics fishery closure (18,19). These policies certainly impact many of the food system and nutrition linkages we explored in this dissertation. Their recent timing precludes rigorous evaluations, though emerging research indicates mixed results. Owusu et al. (2023) found that many canoe fishermen disagreed with the fishery closure and perceived that it would harm their livelihoods (20). And, while freshwater production has steeply grown in recent years, tilapia farmers are experiencing lower profit margins due relatively high input costs (17). To understand the costs and benefits of these policies, studies might build dynamic models of Ghana's food system to simulate policy effects over varying timescales.

5.5 Public health and sustainability implications

There is a complex network of linkages between food systems and nutrition in LMICs (2). In recognizing these underlying complexities, researchers and policymakers are increasingly calling for multisectoral food systems interventions to address new and persistent malnutrition challenges, such as the triple burden of malnutrition (1). Across three studies in this dissertation, we use biodiversity to illuminate specific linkages between food systems and nutrition, which could be used as a roadmap for these interventions. Overall, we found several variations in consumer behaviors that are distinguishable by fish and seafood species/genera, and we discuss several ways these variations can impact diet quality, nutrient intake, and nutrition status in Ghana. Future research can use biodiversity for similar purposes in analogous contexts where fish and seafood is highly consumed.

We also corroborate existing literature that describes the role biodiversity in supporting food systems and nutrition. However, biodiversity loss is rapidly accelerating, often due to the same drivers of food systems transformation (21). In fact, our current understanding of food systems transformation and the nutrition transition points to a paradoxical trend in monotonous diets diversifying around the same types of foods (22,23). Research that highlights how biodiversity contributes to our health and wellbeing is essential for provoking action to preserve it. Fortunately, biodiversity conservation is increasingly prioritized as part of global agendas, as evidenced by the countries of the United Nations adopting biodiversity conservation targets in a global biodiversity agreement in 2021 (24).

5.6 References

1. Brouwer ID, McDermott J, Ruben R. Food systems everywhere: Improving relevance in practice. Global Food Security. 2020 Sep;26:100398.

2. HLPE. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: Committee on World Food Security; 2017. Report No.: 12.

3. Béné C, Prager SD, Achicanoy HAE, Toro PA, Lamotte L, Cedrez CB, et al. Understanding food systems drivers: A critical review of the literature. Global Food Security. 2019 Dec;23:149–59.

4. Reardon T, Tschirley D, Liverpool-Tasie LSO, Awokuse T, Fanzo J, Minten B, et al. The processed food revolution in African food systems and the double burden of malnutrition. Global Food Security. 2021;28:100466.

5. Christian AK, Dake FA. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: prevalence and influencing household factors. Public Health Nutr. 2022 Jun;25(6):1563–76.

6. Gómez MI, Barrett CB, Raney T, Pinstrup-Andersen P, Meerman J, Croppenstedt A, et al. Post-green revolution food systems and the triple burden of malnutrition. Food Policy. 2013 Oct;42:129–38.

7. Meenakshi JV. Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics. 2016 Nov;47(S1):115–34.

8. Pinstrup-Andersen P. Agricultural research and policy for better health and nutrition in developing countries: a food systems approach: Agricultural research and policy for better health and nutrition in developing countries. Agricultural Economics. 2007 Dec 19;37:187–98.

9. Popkin BM. Nutritional Patterns and Transitions. Population and Development Review. 1993;19(1):138–57.

10. Bogard JR, Farook S, Marks GC, Waid J, Belton B, Ali M, et al. Higher fish but lower micronutrient intakes: Temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh. PLoS One. 2017;12(4):e0175098.

11. Ministry of Food and Agriculture and University of Ghana School of Public Health. Food-Based Dietary Guidelines [Internet]. 2023. Available from: https://mofa.gov.gh/site/images/pdf/Ghana_Food_Based_Dietary_Guidelines_2023.pdf

12. Jones AD. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. Nutrition Reviews. 2017 Oct 1;75(10):769–82.

13. Lachat C, Raneri JE, Smith KW, Kolsteren P, Van Damme P, Verzelen K, et al. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. Proc Natl Acad Sci USA. 2018 Jan 2;115(1):127–32.

14. Daelmans B, Ferguson E, Lutter CK, Singh N, Pachón H, Creed-Kanashiro H, et al. Designing appropriate complementary feeding recommendations: tools for programmatic action: Tools for programmatic action. Matern Child Nutr. 2013 Sep;9:116–30.

15. Bai Y, Alemu R, Block SA, Headey D, Masters WA. Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. Food Policy. 2021 Feb;99:101983.

16. Ragasa C, Andam KS, Asante SB, Amewu S. Can local products compete against imports in West Africa? Supply- and demand-side perspectives on chicken, rice, and tilapia in Ghana. Global Food Security. 2020;26.

17. Ragasa C, Agyakwah SK, Asmah R, Mensah ETD, Amewu S, Oyih M. Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana. Aquaculture. 2022 Jan;547:737476.

18. Apetorgbor S. Closed Season Brief. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018 p. 10. Report No.: GH2014_POL109_CRC.

19. Lazar N, Yankson K, Blay J, Ofori-Danson P, Markwei P, Agbogah K, et al. Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island; 2018. Report No.: GH2014_SCI042_CRC.

20. Owusu V, Adu-Boahen K, Kyeremeh S, Demalie I, Eshun P. Factors influencing compliance of closed fishing season: lessons from small-scale coastal fisheries in the Central Region of Ghana. Humanit Soc Sci Commun. 2023 Jan 17;10(1):20.

21. Benton TG, Bieg C, Harwatt H, Pudasaini R, Wellesley L. Food system impacts on biodiversity loss: three levers of food system transformation in support of nature [Internet]. London: Chatham House; 2021. Report No.: 208223. Available from: https://www.ciwf.com/media/7443948/food-system-impacts-on-biodiversity-loss-feb-2021.pdf

22. Drewnowski A, Popkin BM. The nutrition transition: new trends in the global diet. Nutrition Reviews. 1997;55(2):31–43.

23. Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proc Natl Acad Sci USA. 2014 Mar 18;111(11):4001–6.

24. Convention on Biological Diversity. COP 15: Nations Adopt For Goals, 23 Targets for 2030 in Landmark UN Biodiversity Agreement [Internet]. 2022. Available from: https://www.cbd.int/article/cop15-cbd-press-release-final-19dec2022