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Enhancing Women's Income and Household Nutrition Through Training in Small-Scale Fisheries Value Chains in Sub-Sahara Africa

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ABSTRACT *This study uses inverse probability weighting and matching estimators to examine the impact of women's training in small-scale fisheries value chain on their incomes, household food security, and dietary quality in four sub-Saharan countries. It further investigates pathways by which training influences households' food consumption. The analysis reveals that households of trained women experience 8–9 percentage points higher food security and 3 percentage points better dietary quality compared to untrained counterparts. Additionally, trained women earn an average of USD 20–25 more than those without training. Cross-country analysis highlights variations in impact, with the strongest improvements in household food security observed in Sierra Leone and Tanzania, while dietary quality gains were most significant in Ghana and Malawi. Incomes of trained women were notably higher in Ghana (USD 31–44) and Malawi (USD 29–39), though results for Tanzania and Sierra Leone were not statistically significant. The study identifies increased fisheries-related income and household fish consumption as the key transmission channels of impact. These heterogenous findings underscore the need for gender-sensitive capacity-building programs that increase women's participation in fisheries. Such programmes must be tailored to the specific dynamics of each country, including entrenched norms and barriers to women's active involvement in the SSF sector.*

HIGHLIGHTS

- *Training women in fisheries' value chains improves their income and enhances their households' food security and dietary quality.*
- *The extent of the effects of women's training varies remarkably across the studied countries*
- *Training impacts households' food security and dietary quality through increased fish consumption and improved income from SSF activities.*

KEYWORDS: Training; small-scale fisheries; income; food security; dietary quality

JEL CLASSIFICATION: J16; Q01; Q18; Q22

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1. Introduction

In sub-Saharan Africa (SSA), where one-third of the world's undernourished people reside, small-scale fisheries (SSFs) represent a cornerstone of local economies, contributing significantly to livelihoods, food security, and nutrition (FAO, 2021, 2023a). SSFs account for 85% of fish harvesters in Africa, provide a source of protein to over 200 million people, and support the livelihoods of approximately 10 million individuals, nearly a quarter of whom are women (FAO, 2023b; March & Failler, 2022). Given their critical role, SSFs are recognised as having immense potential to advance progress toward the Sustainable Development Goals (SDGs) in SSA, particularly reducing hunger (SDG2), alleviating poverty (SDG1), and combating malnutrition and nutritional deficiencies (SDG 3). However, despite their importance, the full potential of SSFs remains untapped, especially in addressing gender inequalities that hinder women's participation and economic empowerment in these value chains (Gonzalez Parrao et al., 2021; Zelasney, Ford, Westlund, Ward, & Riego Peñarubia, 2020).

This study seeks to address two central questions: (*i*) How does women's participation in training programs focused on SSF value chains affect their incomes, as well as household food security and dietary quality? (*ii*) What pathways drive these effects? These questions are critical because women play a pivotal role in SSF value chains, particularly in post-harvest activities such as processing, marketing, and trading (Franz, Smith, & Westlund, 2019). For instance, in West Africa, women constitute half of the inland fisheries labour force and are responsible for nearly 60% of post-harvest activities, including dressing, sorting, salting, drying, and smoking fish. Yet, women's contributions to SSF value chains often go economically uncompensated and socially unrecognized, with their roles particularly undervalued in fisheries management and policy development (Gonzalez Parrao et al., 2021). This under-acknowledgement stems from a host of economic, social, and cultural barriers, including limited access to financial services, restricted market access, lack of secure land tenure rights, and poor representation in SSF cooperatives and associations (Lawless, Cohen, Mangubhai, Kleiber, & Morrison, 2021; Zelasney et al., 2020). These barriers collectively constrain women's ability to maximize the benefits of their participation in SSF value chains (Johnson, Kovarik, Meinzen-Dick, Njuki, & Quisumbing, 2016; Morgan, Terry, Rajaratnam, & Pant, 2017).

Over the past few decades, gender-transformative approaches have been proposed to address these structural barriers to gender equality in SSF sectors in SSA, challenge discriminatory legislative and policy frameworks, shift power dynamics, and promote women's empowerment in these value chains (FAO, IFAD, & & WFP, 2021; Hillenbrand, Karim, Mohanraj, & Wu, 2015). Central to these efforts are training programs that build women's technical knowledge and entrepreneurial skills, enhancing their capacity to make informed decisions and manage resources effectively (Torre, Hernandez-Velasco, Rivera-Melo, Lopez, & Espinosa-Romero, 2019). Specifically, existing studies suggest that such training can improve women's access to resources, increase productivity and incomes, shift social norms, and enhance household food security and nutrition outcomes (Abu Hatab, 2014; Duflo, 2012; Ragasa, Amewu, Agyakwah, Mensah, & Asmah, 2022). Recognizing this potential, national governments and development partners in SSA have increasingly invested in capacity-building initiatives to equip women with the skills and knowledge needed to adopt sustainable fishing practices, boost productivity, and improve household food security (Tikadar et al., 2022; USAID, 2018).

Despite these efforts, the literature on SSFs in SSA reveals four critical gaps. First, few empirical studies have evaluated the impact of women's training in SSF value chains on their incomes and household food security (Frangoudes, Gerrard, & Kleiber, 2019; Solano, Lopez-Ercilla, Fernandez-Rivera Melo, & Torre, 2021). While research on women's training in agri-food value chains is abundant, it predominantly focuses on livestock and crop value chains, with limited attention to SSFs. Second, existing studies often conflate SSFs with aquaculture, despite their distinct characteristics. SSFs involve harvesting wild fish populations, while aquaculture focuses on cultivating aquatic organisms (FAO, 2023b). Third, the literature on

women's training and food security has primarily examined indicators related to food availability and accessibility, with insufficient attention to dietary quality (Ahmed et al., 2024; Darrouzet-Nardi et al., 2016). Given women's central role in household nutrition, training in SSF value chains could have far-reaching impacts on dietary quality (Darrouzet-Nardi et al., 2016). Fourth, while some studies have explored the direct effects of training on food security, less attention has been paid to the pathways through which these impacts are realized (Mahmud, Kabir, Islam, & Hilton, 2012).

This study addresses these gaps by examining the impact of women's participation in SSF training programs on their incomes and household food security in four SSA countries: Ghana, Malawi, Sierra Leone, and Tanzania. Using data from baseline surveys conducted by the Food and Agriculture Organization (FAO) and the Norwegian Agency for Development Cooperation (Norad) in 2021, we assess changes in incomes among women who received SSF training as well as changes in their household food security and dietary quality. Furthermore, we investigate two key pathways through which training influences outcomes: (1) a direct pathway linking training to increased household fish consumption, and (2) an indirect pathway connecting income from SSF activities to improved food consumption and dietary quality. Our findings provide critical insights for policymakers and stakeholders aiming to design gender-sensitive interventions that enhance women's economic opportunities, improve household food security, and promote better nutrition in rural SSA.

The remainder of the paper is structured as follows. Section 2 provides an overview of women's roles in SSF value chains in the studied countries. Section 3 presents the conceptual framework, outlining the hypothesized links between women's training, incomes, food security, and dietary quality. Section 4 describes the methodology and data used in the econometric analysis. Section 5 presents and discusses the findings. Section 6 concludes with policy recommendations and implications for future research.

2. A brief overview of women's role in SSF in the countries surveyed

In all four countries, the SSF sector plays a vital role in both national economies and household livelihoods, though its impact varies depending on the sector's level of development. In Ghana, fisheries contribute approximately 3.5% to the country's gross domestic product (GDP) and provide employment for about 10% of the population. In Tanzania, the sector accounts for 1.8% of GDP, directly employing around 400,000 people, while more than 4.5 million individuals rely on fisheries-related activities for their livelihoods (Wabnitz et al., 2023). In Sierra Leone, fisheries contribute roughly 12% of GDP and support over 500,000 jobs. Meanwhile, in Malawi, the sector represents about 7% of GDP, directly employing 63,000 fishers and indirectly supporting over 500,000 individuals (FAO, 2022a).

Women in these countries play a crucial role in both marine and inland SSF, engaging in activities across the entire value chain, from pre-harvest to post-harvest, including marketing and consumption (FAO, 2023b). In all four countries, women are underrepresented in the harvesting phase of the value chain due to restrictive gender norms. While men primarily handle fishing, particularly in the marine sector, women are heavily involved in post-harvest processing and distribution (FAO, 2023b). In Sierra Leone, for example, women make up 57% of those engaged in fish processing and 55% in marketing within the SSF sector. Their roles include gutting, cleaning, fish smoking, marketing and distribution, and hand-fishing with scoop nets, pots and traps (Wabnitz et al., 2023).

In Tanzania, over 228,000 women are actively involved in the fisheries sector, particularly in pre- and post-harvest activities. They constitute approximately half of the labour force in subsistence fishing and two-thirds of those engaged in fish trading. They play a key role in various aspects of the industry, including net repair, gear preparation, gleaning, shallow-water and boat fishing, catch sorting, offloading sardines, fish processing, marketing, trading, and cooking in

fishing camps. In the case of Malawi, SSF employs more than 70,000 women, who represent around 70% of fish traders and processors (Kadongola & Ahern, 2023). They also take part in fishing activities in rivers or flood plains, with hook and line, traps or small nets (FAO, 2020). Estimates suggest that nearly 90,000 women in Ghana rely on the SSF sector for their livelihoods. Largely engaged in post-harvest activities, 48% are traders, 36% are fish processors and 9% engaged in fish harvesting for sale (FAO, 2023a).

SSF fisheries are vital for food security, nutrition, and livelihoods in all three countries where food insecurity remains a policy issue. For example, acute food insecurity in Malawi rose from 20% (3.8 million people) in 2022 to 31% (4.4 million) in 2024. In Tanzania, the figure increased from 10% (1.1 million people) to 13% (0.9 million) (FAO, 2023c), while in Sierra Leone, it remained steady at 19%, affecting 1.6 million people in 2022 and 1.5 million in 2024(FSIN & Global Network Against Food Crises, 2024). In the case of Ghana, food insecurity stands at 11.7% (3.6 million people) (MoFA, GSS, WFP, & FAO, 2020), but February 2024 estimates indicated that there were 5.4 million people (18.12%) with insufficient food consumption (AGRA, 2024).

The SSF sectors in these countries provide essential nutrition, particularly for children and vulnerable populations. In Tanzania, Fish consumption is estimated at 8 kg per capita per year and contributes between 20% and 30% of animal protein intake (Wabnitz et al., 2023). Fish consumption in Sierra Leone is estimated at 26.3 kg per person per year, with fish providing about 80% of animal-sourced protein intake in local diets (Wabnitz et al., 2023). In Ghana, fish accounts for at least 54% of animal protein intake, with per capita consumption estimated at 25 kg per year (FAO, 2019; Hasselberg et al., 2020). Annual per capita fish consumption in Malawi is estimated at 11.6 kg, which falls below the World Health Organization's (WHO) recommended average of 17 kg. Fish contributes approximately 30% of the country's animal protein intake and around 5% of total protein intake (FAO, 2022b). Women play a crucial role in ensuring food and nutrition security, as they are primarily responsible for sourcing and preparing food for households.

It is therefore evident that the SSF sector in these countries is characterised by a gendered division of labour, which seems to disadvantage women. However, both the economic importance of SSF and the active engagement of women in SSF value chains suggest that empowering women through training and capacity building may enhance their economic opportunities, generating positive spillovers for their incomes, and for their households' food security and nutrition. Strengthening women's roles, improving access to resources, and ensuring sustainable fishery management can create long-term benefits for both livelihoods and national economies.

3. Conceptual framework

From the perspective of a theory of change, Figure 1 outlines our conceptualisation of the anticipated impact of women's training in SSF value chains on their incomes and on their households' food security and dietary quality. The training interventions encompassed fishing techniques, fish storage and processing methods, fish trading and marketing, as well as food safety and nutrition. Most training sessions were conducted by fisheries extension workers from the government fisheries department or ministry as well as other organizations including National Fish Processors and Traders Association (NAFPTA), the Sustainable Fisheries Management Project (SFMP), Friends of the Nation (FON), and Cerath Development Organization (Kadongola & Ahern, 2023). These training activities were expected to yield positive outcomes, including improved entrepreneurial skills, as indicated by previous studies (Idrus, Pauzi, & Munir, 2014); better access to financial services such as loans and credit (Béné et al., 2016; Wen & Owren, 2020); improved knowledge and adoption of sustainable fishing practices (Torre et al., 2019) improved hygiene practices during fish processing (Asiedu et al.,

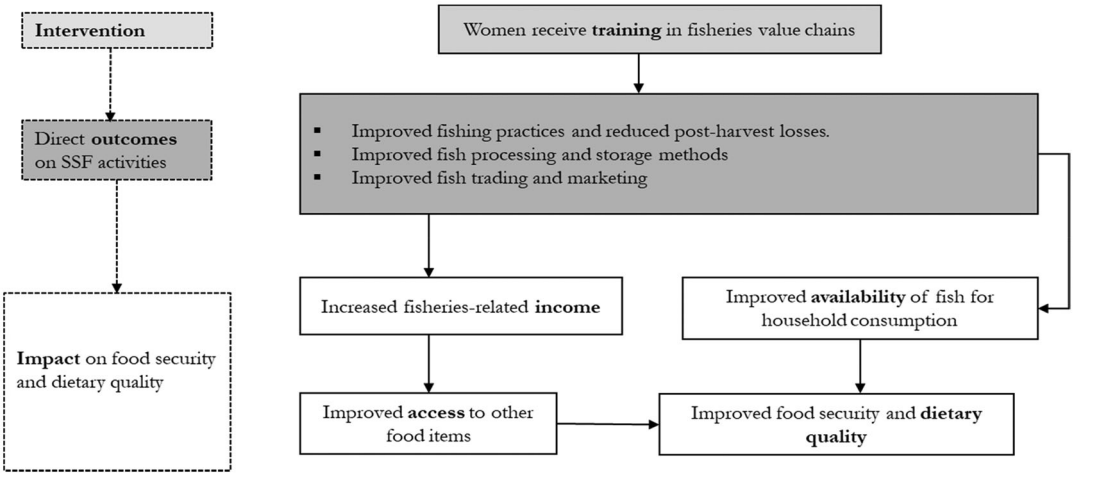

Figure 1. Training in fisheries value chains, women's income and their households' food security and dietary quality.
Source: Author's own construct.

2020); and reduced fish loss and waste throughout the value chain (Batalofo et al., 2023). However, the survey data does not allow us to assess evidence of knowledge acquisition attributable to the training.

In addition, women's training in fish-processing methods may enable them to add value to their products, which could open up premium markets for processed fish that often command higher prices (FAO, 2016). Training women in fish trading and marketing may also increase their bargaining power and provide them with better market information that helps them make informed decisions about when and where to sell their fish products for optimal profit (Matsue, Daw, & Garrett, 2014). Subsequently, these positive outcomes are envisaged to improve the incomes and household food security of women who receive training, which is also ubiquitously established in the literature (Aziz, Nisar, Koondhar, Meo, & Rong, 2020; Clement et al., 2019; Mahmud et al., 2012; Nyaki, 2020). As depicted in Figure 1, these impacts are realised through multiple channels, but principally through two. The first (direct) channel is through increasing the availability of fish for household consumption. This is particularly important in coastal and inland communities where fish is a primary source of households' protein and essential nutrients, such as vitamin A, calcium, iron and zinc (Dasgupta, Mustafa, Paul, & Wheeler, 2021; Kawarazuka & Béné, 2010).

The second (Indirect) channel is through increasing women's disposable incomes, as improved fishing techniques and knowledge of sustainable practices due to training can increase catch rates and improve fish quality, leading to higher market prices and greater income for fisherwomen. As women experience higher earnings from SSF activities, they are empowered to actively participate in decisions related to household expenditure and food consumption. This, in turn, contributes significantly to their households' food security and dietary quality.

Therefore, in accordance with the conceptual model presented in Figure 1, we empirically examine three interconnected hypotheses: (1) women who engage in training in the SSF value chain attain higher income from fisheries activities compared to their counterparts who have not participated in such training programmes; (2) households with women who take part in training in the SSF value chains achieve greater food security outcomes than households of women who have not engaged in these training programmes; and (3) households with women

participating in training in the SSF value chain exhibit improved dietary quality in comparison to households of women not involved in training programmes.

4. Method and data

4.1. Description of the intervention and the dataset

The collaborative FAO-Norad project "Empowering Women in Small-scale Fisheries for Sustainable Food Systems" was implemented in Ghana, Malawi, Sierra Leone, Tanzania and Uganda, to support FAO in implementing the Voluntary Guidelines for Securing Sustainable Small-scale Fisheries (SSF Guidelines) within the framework of food security and poverty eradication (FAO, 2022a). However, this paper focuses on four countries, excluding Uganda, due to the lack of available data during the empirical analysis. The overall goal of the project was to promote greater gender equality and enhance women's inclusion in SSF value chains, increase women's incomes from fishing activities, and enhance household nutrition and dietary outcomes. To accomplish this goal, baseline surveys were carried out from September 2020 to February 2021[1] to gain deeper insights into gender-related dynamics and women's roles in the SSF sectors in the four countries. The survey was also intended to understand the links between women's participation in training programmes in SSF value chains and their households' food security and nutrition.

A semi-structured instrument was used to gather this information through individual-level surveys, which covered a wide range of aspects related to women's involvement in SSF value chains. These included questions on how women acquire and consume fish; their experiences with food security and dietary practices; their participation in fisheries governance and organisations; and their participation in training in fisheries activities such as post-harvest handling, processing, marketing, and other relevant skills (Kadongola & Ahern, 2023). Information was collected on participants' sociodemographic characteristics, including education level, age, marital status, household size, income, ownership of fisheries assets, gender attitudes toward work and decision-making in SSF value chains and households.

4.2. Sampling strategy

A stratified sampling approach was used to select 300 women per country, with sample sizes determined by district and landing site. After defining the strata, random sampling is used to ensure fair subgroup representation. Additionally, a non-random sample of women was selected opportunistically for focus group discussions, typically held twice per district or region as part of the project's baseline assessment. A purposive sampling method was also used to select ten key informants based on the national project coordinator's expertise, with input from the government and local leaders. According to FAO, the global small-scale fisheries population is 120 million, with 90% (108 million) engaged in primary or secondary activities. Of these, 97% (104.76 million) live in developing countries, and women comprise 50% (52.38 million) (Kadongola & Ahern, 2023).

With a 95% confidence level and a 2.5 confidence interval, the expected sample size was 1,536 women across the five countries. As shown in Table A1, Malawi and Sierra Leone exceeded this by 2% and 44%, while Ghana and Tanzania fell short by 1% and 7%. Sample sizes in results Tables 2–6 may differ from those in Table 1 due to variations in the key variables and covariates. The dataset initially included 60 males from Sierra Leone and 5 from Tanzania, but they were excluded as the study focused on women.

Table 1. Description of the variables included in the analysis

Variable	Variable type and measurement	Full sample			Ghana			Tanzania			Malawi			Sierra Leone		
		N	Yes%	Mean	*N*	Yes%	Mean	*N*	Yes%	Mean	*N*	Yes%	Mean	*N*	Yes%	Mean
Training	Binary (1 Participant; 0 Non-participant)	1,248	30.560		294	43.240		277	19.490		306	18.950		371	49.72	
Food security	Continuous (index, %)	1,248		38.973	294		56.698	277		31.205	306		47.958	371		23.248
Dietary quality	Continuous (index, %)	1,232		43.932	291		51.570	277		47.793	304		55.263	360		36.875
Income	Continuous variable (USD)	1,248		119.799	294		153.847	277		62.426	306		168.508	371		94.269
Fish consumption	Count (days per week of fish consumption)	1,240		5.760	294		6.690	277		4.491	306		4.781	363		6.799
Autonomy	Continuous (autonomy over fisheries activities-index, %)	1,248		65.500	294		71.300	277		52.800	306		73.800	371		63.400
Access to asset	Continuous (access to productive access index, %)	1,248		60.270	294		66.12	277		41.65	306		69.31	371		62.09
Age (20–31 years)	Binary (1 Yes; 0 No)	1,199	13.580		294	8.930		277	19.860		306	11.760		322	13.210	
Age (32–11 years)	Binary (1 Yes; 0 No)	1,199	18.680		294	54.910		277	12.270		306	20.450			16.440	
Age (52–81 years)	Binary (1 Yes; 0 No)	1,199	67.740		294	36.160		277	67.870		306	87.580			70.350	
Education (none)	Binary (1 Yes; 0 No)	1,210	36.600		294	44.960		277	17.33		287	4.880		352	71.020	
Education (Basic)	Binary (1 Yes; 0 No)	1,210	58.040		294	44.240		277	79.060		287	93.730			23.300	
Education (Secondary plus)	Binary (1 Yes; 0 No)	1,210	5.360		294	10.790		277	3.610		287	11.390			5.680	
Marital status (Single)	Binary (1 Married; 0 Single)	1,247	71.540		294	65.880		277	55.880		306	78.760		370	81.620	
Household size	Binary (1 More than 5 household members; 0 1–5 members)	1,240	52.230		294	69.550		277	54.510		306	64.380		363	28.650	
Fishing	Binary (1 fishing; 0 otherwise)	1,248	51.520		294	47.640		277	37.180		306	37.580		371	76.820	
Fish processing	Binary (1 fish processing; 0 otherwise)	1,248	21.520		294	7.770		277	12.640		306	66.670		371	11.890	
Fish trade	Binary (1 fish trading; 0 otherwise)	1,248	43.520		294	46.280		277	25.990		306	39.540		371	57.680	
Other business	Binary (1 engaged in other business; 0 otherwise)	1,248	50.160		294	17.910		277	23.100		306	56.210		371	91.110	

Source: Authors' computation based on FAO (2023a).

Table 2. Impact of training on incomes, households' food security and dietary quality

Estimates	Inverse probability weighted estimators				Matching estimators	
	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE—Food security	9.113***	8.877***	8.920***	9.158***	8.037***	7.468***
	(2.337)	(2.313)	(2.347)	(2.379)	(2.866)	(2.715)
PO mean	36.798***	36.726***	36.721***	36.767***		
	(1.180)	(1.179)	(1.179)	(1.182)		
Observations	1,199	1,199	1,199	1,199	1,199	1,199
Tebalance Does test (p-value)	0.178	0.178	0.178	0.178		
ATE—Dietary quality index	3.052***	2.952***	2.934***	3.071***	2.676**	2.932**
	(1.088)	(1.069)	(1.071)	(1.078)	(1.351)	(1.240)
PO mean	43.261***	43.220***	43.216***	43.243***		
	(0.620)	(0.618)	(0.618)	(0.619)		
Observations	1,184	1,184	1,184	1,184	1,184	1,184
Tebalance test (p-value)	0.250	0.250	0.250	0.250		
ATE—Fishing-related income (USD)	20.961**	21.888***	21.578**	20.897**	25.039**	19.873**
	(8.387)	(8.292)	(8.381)	(8.377)	(10.631)	(9.003)
PO mean	99.743***	99.128***	99.131***	99.176***		
	(3.843)	(3.801)	(3.803)	(3.794)		
Observations	1,169	1,169	1,169	1,169	1,169	1,169
Tebalance test (p-value)	0.386	0.386	0.386	0.386		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

Table 3. Impact of training on incomes, households' food security and dietary quality in Ghana

Estimates	Inverse probability weighted estimators				Matching estimators	
	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE – Food security	4.395	4.651	4.775	4.459	2.689	2.407
	(4.439)	(4.331)	(4.389)	(4.660)	(4.943)	(5.288)
PO mean	56.221***	56.401***	56.406***	56.627***		
	(2.937)	(2.902)	(2.910)	(2.959)		
Observations	296	296	296	296	296	296
Tebalance test (*p*-value)	0.824	0.824	0.824	0.824		
ATE – Dietary quality index	4.932**	4.982**	4.875**	4.668**	5.423*	3.157
	(2.027)	(2.026)	(2.006)	(2.026)	(2.804)	(2.504)
PO mean	49.518***	49.402***	49.423***	49.475***		
	(1.299)	(1.276)	(1.291)	(1.326)		
Observations	293	293	293	293	293	293
Tebalance test (*p*-value)	0.878	0.878	0.878	0.878		
ATE – Fishing-related income (USD)	30.778**	32.530**	31.771**	32.850**	43.725***	33.804**
	(14.323)	(13.929)	(14.242)	(13.991)	(15.870)	(15.004)
PO mean	118.790***	119.064***	119.460***	119.019***		
	(8.669)	(8.443)	(8.508)	(8.310)		
Observations	288	288	288	288	288	288
Tebalance test (*p*-value)	0.821	0.821	0.821	0.821		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

Table 4. Impact of training on incomes, households' food security and dietary quality in Malawi

Estimates	Inverse probability weighted estimators				Matching estimators	
	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE – Food security	6.884	6.106	6.080	6.737	11.323*	6.596
	(5.615)	(5.235)	(5.533)	(5.434)	(5.832)	(6.073)
PO mean	48.112***	47.994***	48.061***	48.123***		
	(2.100)	(2.099)	(2.099)	(2.097)		
Observations	287	287	287	287	287	287
Tebalance test (*p*-value)	0.898	0.898	0.898	0.898		
ATE – Dietary quality index	3.973**	3.612**	3.668**	3.458**	2.381	3.484**
	(2.068)	(1.976)	(1.998)	(2.013)	(2.346)	(2.427)
PO mean	40.886***	40.916***	40.914***	40.899***		
	(0.800)	(0.804)	(0.803)	(0.799)		
Observations	286	286	286	286	286	286
Tebalance test (*p*-value)	0.970	0.970	0.970	0.970		
ATE – Fishing-related income (USD)	38.716**	38.716**	37.910**	39.151**	32.651**	29.086*
	(22.321)	(22.321)	(22.240)	(22.152)	(19.211)	(24.802)
PO mean	149.689***	149.689***	149.762***	149.299***		
	(9.494)	(9.494)	(9.468)	(9.339)		
Observations	282	282	282	282	282	282
Tebalance test (*p*-value)	0.898	0.898	0.898	0.898		

Note: Robust standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

Table 5. Impact of training on incomes, households' food security and dietary quality in Sierra Leone

	Inverse probability weighted estimators				Matching estimators	
Estimates	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE – Food security	6.498**	6.861**	6.154**	6.276**	4.777	6.732**
	(3.137)	(2.834)	(3.066)	(3.197)	(3.353)	(3.144)
PO mean	20.347***	20.487***	20.396***	20.445***		
	(1.537)	(1.550)	(1.547)	(1.560)		
Observations	344	344	344	344	344	344
Tebalance test (*p*-value)	0.946	0.946	0.946	0.946		
ATE – Dietary quality index	3.818*	4.119*	3.878*	3.618	4.515**	3.073
	(2.221)	(2.106)	(2.157)	(2.402)	(2.104)	(2.351)
PO mean	36.871***	36.965***	37.020***	37.136***		
	(1.354)	(1.342)	(1.343)	(1.358)		
Observations	333	333	333	333	333	333
Tebalance test (*p*-value)	0.944	0.944	0.944	0.944		
ATE – Fishing-related income (USD)	5.416	3.224	4.082	5.907	1.979	5.980
	(9.385)	(8.495)	(8.810)	(9.254)	(10.425)	(15.192)
PO mean	71.277***	70.930***	70.806***	70.987***		
	(5.963)	(5.985)	(5.959)	(5.897)		
Observations	327	327	327	327	327	327
Tebalance test (*p*-value)	0.946	0.946	0.946	0.946		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

Table 6. Impact of training on incomes, households' food security and dietary quality in Tanzania

	Inverse probability weighted estimators				Matching estimators	
Estimates	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE – Food security	12.763**	14.211***	14.444***	16.047**	17.623***	11.360*
	(4.962)	(3.977)	(4.137)	(7.412)	(5.024)	(5.876)
PO mean	28.644***	28.742***	28.760***	28.785***		
	(2.242)	(2.226)	(2.229)	(2.228)		
Observations	272	277	277	277	277	277
Tebalance test (*p*-value)	0.717	0.717	0.717	0.717		
ATE – Dietary quality index	0.228	0.731	0.115	0.617	1.187	−0.372
	(2.502)	(2.550)	(2.303)	(2.937)	(2.294)	(3.191)
PO mean	47.261***	47.248***	47.292***	47.338***		
	(1.136)	(1.148)	(1.144)	(1.136)		
Observations	272	272	272	272	277	277
Tebalance test (*p*-value)	0.717	0.717	0.717	0.717		
ATE – Fishing-related income (USD)	16.896	16.896	24.983	62.520	19.255	13.034
	(24.954)	(24.954)	(18.603)	(54.412)	(26.778)	(18.701)
PO mean	60.899***	60.899***	60.815***	60.958***		
	(4.163)	(4.163)	(4.142)	(4.145)		
Observations	272	272	272	272	272	272
Tebalance test (*p*-value)	0.420	0.420	0.420	0.420		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

4.3. Instrumentation

We address the objectives of this study by distinguishing participants from non-participants, using a dummy variable that took the value 1 if a respondent had received training on fisheries activities or food safety and nutrition in the past 12 months and 0 otherwise. However, the share of women who underwent training varied significantly between the four countries. Sierra Leone led with 50%, followed by Ghana with 43%, whereas Malawi and Tanzania had notably lower rates at 19% each. Such limited engagement in training can be ascribed to the inefficiency and inadequacy of women-tailored extension services, as nearly half of the surveyed women reported no interactions with officers from SSF extension services in the past 12 months.

The Food Insecurity Experience Scale (FIES-SM) was utilised to assess the effect of training on households' food security. The FIES-SM assesses the extent and severity of food insecurity at individual or household levels over a specified period, usually the past 12 months. The scale is based on eight sets of binary response questions (see Table S1 in the supplementary file) that take the value 1 if a household representative responds "no" to a particular question in relation to the household's experience of food insecurity in the past 12 months and takes 0 if the response is "yes." The positive responses to all eight variables were subsequently added together to arrive at the household's food security experience rather than its food insecurity experience. The food security index in all four countries averaged 39%, but it varied from 23% in Sierra Leone to 31% in Tanzania, 48% in Malawi and 57% in Ghana.

Regarding the impact of women's training on their households' dietary quality, we used a household dietary quality index (HDQI), which assesses the variety of foods consumed within a household over a specified period. This index is calculated using a set of 22 binary response questions (see Table S2 in the supplementary file) that take the value 1 if a respondent indicates that their household did not eat a particular food on the day preceding the survey, and 2 otherwise. Following Mehraban and Ickowitz (2021), the 22 variables were classified under 12 food items, namely: cereals; roots and tubers; vegetables; fruits; meat (including poultry and offal); eggs; fish and seafood; pulses/legumes/nuts; milk and milk products; oils/fats; sugar/honey; and miscellaneous/condiments. As presented in Table S2 in the supplementary file, each of these classes of food items was recoded to take the value 1 if the household of a respondent ate any food items the previous day, and 0 otherwise. A similar additive approach was used to compute the HDQI. The overall value of the index averaged 44% in all four countries, with the highest value observed in Malawi (55%), Ghana (52%), followed by Ghana, Tanzania (48%) and finally Sierra Leone (37%).

The third dependent variable of interest is the respondent's income from SSF activities. This was originally measured as the estimated monthly income from fisheries activities in local currency units. To enable cross-country comparisons and ensure consistency, we converted these income estimates to USD using the average annual exchange rates for 2021, the year the survey was conducted. In 2021–22, the average USD was equal to 5.81 Ghanaian cedi (GHS), 2,297.72 for the Tanzanian shilling (TZS), 805,90 for the Malawian kwacha (MWK), and 10,440 for the Sierra Leone leone (SLL). Table 2 shows that the average income for all four countries was USD130 per month (USD154 in Ghana, USD168 in Malawi, USD91 in Sierra Leone and USD62 in Tanzania).

Consistent with the conceptualization in Figure 1, income from fisheries and fish consumption frequency are the two primary pathways through which training impacts household food security and dietary quality. Ideally, the best measure of fish consumption would be the quantity of fish consumed. However, the survey data recorded fish consumption in varying units, complicating direct incorporation into the analysis. As a result, we used the number of days households consumed fish as a proxy. Table 1 presents the covariate measurements, with two variables derived from a set of binary response questions. One such variable is autonomy, which was computed from six variables that measure women's role in household decision-making on fish-related and other activities such as fishing, fish buying, processing, storage,

transportation, marketing (selling/trading) and other income-generating activities. The other variable is access to productive assets, which was computed from six binary response questions on respondents' access to equipment for fishing, fish transportation, processing and storage, and means of communication (e.g. cell phone).

4.4. Estimation techniques

In an ideal scenario without confoundedness, a pure randomised control trial would have been the optimal approach for evaluating the impact of training of this kind on women's incomes and their households' food security. However, the presence of confoundedness is an inherent characteristic of observational data, primarily due to non-random assignment or the influence of selection bias. Failure to address confoundedness may result in either overestimation or underestimation of the true effect (Chesnaye et al., 2022). One of the estimation techniques used to address confoundedness in observational data analysis is the inverse probability weighting (IPW) method, which can be implemented in a two-step process. The first step involves computing the propensity score $\hat{p}(X_i)$, which is defined as the conditional probability of receiving the treatment (i.e. participating in training on SSF) given an individual's characteristics. This can be specified as Equation (1), where the probability that a woman (i) would receive training in SSF $(Train)$ is a function of a vector of her characteristics X.

$$Prob(Train_i = 1|X_i) = \beta_0 + \beta_i X_i + \mu_i \tag{1}$$

The covariates of Equation (1) (see Table 1) are the woman's age, level of education, marital status and household size. We also included a set of binary variables which capture the type of economic activities (fishing, fish processing, fish trade and other business) in which a surveyed woman is engaged. Equation (2) is the estimated version of Equation (1) where $\hat{p}(X_i)$ is the propensity score.

$$\hat{p}(X_i) = Pr(Train_i = 1|X_i) \tag{2}$$

Having estimated the propensity score, the next step of the IPW method involves calculating each individual's weight as the inverse of the probability of receiving actual exposure. The estimated propensity score uses $1/\hat{p}(X_i)$ to weight observation in the treatment group and $1/1 - \hat{p}(X_i))$ to weight observations in the untreated (control) group. This means that observations with a large $\hat{p}(X_i)$ are overrepresented in the treatment group and thus weighted down when treated. The same observations are weighted up when untreated and the opposite applies to observations with a small $\hat{p}(X_i)$. This estimator is modifiable, so that the weights in each treatment arm sum to 1, which produces an improvement in finite sample performance (Abadie & Cattaneo, 2018).

$$\hat{\varphi}_{ATE=\frac{1}{n}} \sum_{i=1}^{n} \frac{Train_i Y_i}{\hat{p}(X_i)} - \frac{(1 - Train_i) Y_i}{1 - \hat{p}(X_i)} \tag{3}$$

$\hat{\varphi}_{ATE}$ in Equation (3) is the IPW estimator. The causal equation for the estimated average treatment effect (ATE) is specified as Equation (4) to (6).

$$\hat{Y}_i = \mathrm{E}(Y_{i1} - Y_{i0}|Tain_i = 1) \tag{4}$$

$$= \mathrm{E}\{\mathrm{E}\{Y_{i1} - Y_{i0}|Train_i = 1, \hat{p}(X_i)\}\} \tag{5}$$

$$= \mathrm{E}\{\mathrm{E}\{Y_{i1} - Y_{i0}|Train_i = 1, \hat{p}(X_i) - E\{Y_{i0}|Train_i = 0, \hat{p}(X_i)\}\} \quad (6)$$

The subscript i represents a woman; φ is the average treatment effect; while D is a binary variable, which takes the value 1 if the respondent received training in any SSF activities, and 0 otherwise. The variable Y represents the outcome variable (FIES-SM, HDQI or income from fisheries activities). The propensity score, $\hat{p}(X_i)$, captures the probability that a respondent would receive training given the covariate (X). One of the conditions for the choice of covariate is that only variables that simultaneously influence the treatment status of receiving training in fisheries activities and the outcome variables should be included in the model. The other condition is that the variables included in the model should not be confounded (Caliendo & Kopeinig, 2008). The outcome variable must be independent of the treatment conditional on the propensity score (Angrist & Kuersteiner, 2011).

Despite its strong causal implications, IPW is sensitive to large differences in characteristics between groups. When some respondents have propensity scores near 0 (for non-participants) or 1 (for participants), taking the inverse can produce extreme weights. This inflates variance and widens confidence intervals, particularly when the exposure is rare in a small subset of individuals who receive disproportionately large weights. To mitigate this, common strategies include removing outliers, stabilizing weights, or applying weight truncation (Chesnaye et al., 2022).

As a validation strategy, we employ matching methods, specifically propensity score matching (PSM) and nearest neighbour matching, which reduce reliance on extreme weights by directly pairing treated and control individuals with similar characteristics. In this analysis, the matching estimators identify participants with comparable observable characteristics—such as age, education, and gender—to non-participants (Abadie & Cattaneo, 2018). Similar to IPW, the first step in PSM involves estimating the propensity score, which represents the predicted probability of participating in training. We estimate these propensity scores [$\mathrm{P}(X_i)$] using a logistic regression, where the probability of participation in a training is modelled based on observable covariates.

In line with the conceptual framework, we examined the pathways by which women's training may influence households' food security and dietary quality by regressing food security and dietary quality on the number of days that their households consume fish (direct pathway) and on women's incomes from fisheries-related activities (indirect pathway). Income is logged to make it consistent with the food security index and HDQI, which are also calculated as percentages. Finally, we present separate results for each country alongside the pooled sample for all four countries to explore intra-country heterogeneities that may influence the impact of the training on women's incomes, household food security, and dietary quality.

4.5. Post-estimation tests

Following Ben-Michael and Keele (2023), two post-estimation tests were conducted to assess the reliability of the treatment effect estimates. The first test was the validation of the overlap assumption, which states that each individual has a positive probability of receiving each treatment level. The density plots obtained from this test for both the treatment and control groups did not reveal any violation of the assumption, as shown in Figures S1 and S2 in the supplementary file. Specifically, neither the estimated density of the predicted probabilities that a woman who did not receive training in SSF value chains received it nor the estimated density of the predicted probabilities that a woman who received training did not receive it shows a significant concentration of probability mass near 0 or 1. This implies that the two estimated densities have most of their respective probability masses in the acceptable regions, and thus we can effectively predict or account for unobserved outcomes for particular individuals.

In addition, the quality of matching was assessed using weighted standardised differences by checking the balance of the covariates that are part of the propensity score for the overall study

population and within the subgroups. Table S3 in the supplementary file shows that the weighted standardised differences of the covariates are close to 0 and the weighted variance ratios are close to 1, implying that the weighting has successfully created conditionally exchangeable groups in terms of measured covariates. Following Imai and Ratkovic (2014), we further present the results of the test of balance for each model in the results tables. The test imposes a restriction as overidentifying conditions and assesses whether the treatment model balances the covariates. A significant p-value means a rejection of the null hypothesis that the treatment model balances the covariates. Insignificant p-values of the tests (see Tables 2–6 and Table A5) indicate that the treatment model indeed balances the covariates.

5. Results

5.1. Descriptive results

Compare-Mean Tests analysis of income, food security and dietary quality based on training status of women (see Tables A2–A4 in the Appendix 1) show a higher food security (44%) for trained women than their untrained counterparts (37%), a significant six percentage point difference at the 1% level. Country-specific trends vary, with Tanzania showing the largest impact – nearly double the food security index of untrained households – while differences in other countries range from 3 percentage point in Ghana to 5 in Malawi.

Dietary quality analysis shows averages of 45% for trained women and 43% for untrained women, with a statistically significant 3-percentage-point difference at the 1% level. Ghana (52%) and Malawi (51%) report higher dietary quality than Tanzania (43%) and Sierra Leone (38%), aligning with broader malnutrition trends. According to the 2022 Global Nutrition Report, stunting, wasting, and anaemia remain prevalent across these countries, underscoring persistent nutritional challenges reflected in dietary quality levels (Development Initiatives, 2022). The average difference in the fisheries-related income of trained and untrained women is USD 37. Malawi reports the highest average income (USD 169), followed by Ghana (USD 153), Sierra Leone (USD 94), and Tanzania (USD 62). The income gap between trained and untrained women is largest in Sierra Leone (USD 52) and Malawi (USD 44), compared to Ghana (USD 37) and Tanzania (USD 5).

5.2. Treatment effect estimates

Table 2 presents the results of the impact of women's training on their incomes, and on their households' food security and dietary quality. By and large, the results reveal that training women in the SSF value chain improves households' food consumption and income from fishing activities. Specifically, with regard to the effect of training on food security, the IPW estimates show that the household of a woman who received training on the SSF value chain in the 12 months preceding the survey was more likely to be about 9 percentage points more food secure than the household of a woman who had not received training during the same period. The matching estimators reveal that if all women were to receive training in the SSF value chain, the average food security index would be approximately 8 percentage points higher than if none of them had received training.

Similar to food security, the results show a statistically significant effect of women's training on the dietary quality of their households. The IPW estimates indicate that, on average, the dietary quality of households with women who had received training in the SSF value chain was slightly more than 3 percent points higher than that of households with women who had not received training. In relation to the propensity score matching estimates, the results indicate that at a 5% level of statistical significance, the average dietary quality of households with women who had received training in the SSF value chain would be 3 percentage points higher than that of households with women who had not received any training.

Regarding the effect of training on income, the results offer strong evidence that training women in the SSF value chain is associated with a positive effect on their incomes. These findings were statistically significant across all estimated models. In this respect, the average SSF-related income of a woman who had received training was about USD 20–25 higher than her counterpart who had not received any training, which might be attributed to country-specific context and dynamics.

5.3. Country-level analysis

Given the possible variations in the effect of training on women's fisheries-related incomes, and their households' food security and dietary quality, we undertook a country-level analysis to provide a more nuanced understanding of the intricacies of these effects in different national contexts. The results of the country-level analysis are presented in Tables 3–6 for Ghana, Malawi, Sierra Leone and Tanzania, respectively.

Concerning the effect of training on food security, the results indicate a positive but statistically weak effect of women's training in SSF value chains on their households' food security. In both Ghana and Malawi, the results in Tables 3 and 4 highlight a positive but statistically insignificant impact of training on households' food security. While the actual reasons for the observed pattern are unknown, it might be due to several factors like the quality of training, effectiveness of the implementation, or other contextual influences. Training enhances fisheries-related skills, increasing incomes, but households may prioritize non-food expenses (e.g. education, healthcare) over food consumption, affecting food security but not dietary quality (Sibhatu & Qaim, 2018). By improving fish handling, processing, and marketing, training boosts the availability and intake of nutrient-rich fish, enhancing dietary diversity without necessarily improving overall food security (Thilsted et al., 2016).

In contrast to the findings for Ghana and Malawi, Tables 5 and 6 demonstrate a highly significant positive impact of women's training in SSF value chains on household food security in Sierra Leone and Tanzania. Specifically, at the conventional (1%, 5% and 10%) levels of statistical significance, the household of a Tanzanian woman who received training in the SSF value chain was approximately 11–18 percentage points more food secure than the household of a woman who did not receive any training. Notably, the extent of the impact of training on household food security is higher in Tanzania than the average impact for the other three countries. In Sierra Leone, the results show that the household of a woman who underwent training in the SSF value chain was about 6–7 percentage points more food secure than a household where the woman never received any training.

Regarding the impact of women's training on dietary quality, the results highlight a heterogeneous effect across the surveyed countries. In particular, the results indicate that the dietary quality of the household of a Ghanaian woman who had received training on the SSF value chain was about 5 percentage points higher than the household of a woman who had not received any training. Similarly, the dietary quality of a household of a Malawian woman who had received training on the SSF value chain was approximately 4 percentage points higher than that of the household of a woman who had not received any training, with statistical significance observed at the 10% level. The effect in Sierra Leone is about 3-5 percentage points and also statistically significant at 10% level. However, the results related to Tanzania indicate a positive but statistically insignificant impact of women's training on their households' dietary quality.

Turning to the effect of SSF-related activities on women's monthly incomes, the results show statistically significant of training in Ghana and Malawi but insignificant effect in Sierra Leone and Tanzania, training women in SSF value chains had a positive and statistically significant impact on their monthly income. Specifically, receiving training in SSF value chains was found

to be associated with higher income of between USD31 and USD44 in Ghana, and between USD33 and USD39 in Malawi.

5.4. Analysis of the impact pathways of women's training in on their households' food security and dietary quality

We explore two impact pathways by which women's training in SSF value chain may affect household food security: frequency of household fish consumption and income generated from SSF-related activities. Table A5 shows that women's training in the SSF value chain was found to contribute to an increase in the number of days households consume fish by an average of 0.4, compared to households where no women received training in the SSF value chain. This association is statistically significant at the 1% level. Moreover, the results in Table A6 reveal a statistically significant effect of women's income from SSF-related activities on their households' food security and dietary quality at the 1% level. These significant effects are consisted across both the Ordinary Least Squares (OLS) and Tobit models, suggesting that participation in training on the SSF value chain may improve households' food security directly by increasing the frequency of household consumption of fish; and, indirectly, by increasing women's income, which enables trained women to purchase other food items that are necessary to meet their households' food security and dietary needs.

6. Discussion and policy implications

Sub-Saharan African (SSA) women engage in all aspects of the small-scale fisheries (SSF) value chain, yet their contributions remain largely uncompensated and unrecognized in fisheries management and policy (Gonzalez Parrao et al., 2021). To address structural barriers to gender equality in SSF, gender-transformative approaches have been proposed, aiming to correct power imbalances and reduce inequality. Central to these approaches is training that enhances women's technical knowledge and entrepreneurial skills in SSF activities (Torre et al., 2019). However, limited empirical research in SSA has assessed the impact of such training on women's incomes, household food security, and dietary quality. This study bridges these gaps by evaluating the effects of women's participation in SSF training programs on these outcomes in Ghana, Malawi, Sierra Leone, and Tanzania.

The empirical results provide strong evidence that households of women trained in SSF value chains are significantly more food secure than those of untrained counterparts. These findings align with previous research demonstrating that women's capacity-building through training positively impacts household food security and nutrition (Clement et al., 2019; Nyaki, 2020). For instance, Mahmud et al. (2012) found that Bangladeshi women's participation in SSF value chain training programs improved household food consumption. This impact arises from enhanced access to financial and productive resources and shifts in social norms and attitudes toward women's participation (Amugsi, Lartey, Kimani-Murage, & Mberu, 2016; Ragasa et al., 2022).

The results indicate a statistically significant impact of women's training on household dietary quality, though the effect is roughly half as strong as its impact on food security. Studies on agrifood value chain training and nutritional education in developing countries have reported similar findings. These results highlight that nutrition knowledge training and agricultural interventions, including skills development, significantly enhance dietary diversity and improve nutritional intake (Al Daccache et al., 2024; Zheng, Ma, & Guo, 2023). Studies (Blakely et al., 2011; Ni Mhurchu, Blakely, Jiang, Eyles, & Rodgers, 2010) suggest that training alone has little or no impact on household dietary quality. However, Ponce and Ramos-Martin (2017) argue its effectiveness increases when combined with development initiatives like cash transfers and food vouchers. Additionally, Women's training is most effective in improving dietary quality

when it takes a comprehensive approach, addressing social, economic, cultural, environmental, and emotional factors (Nyanzu, 2022).

Our results further provide strong evidence that training women in the SSF value chain significantly increases fisheries-related incomes. This aligns with prior research which conclude that well-designed training increases income, fosters empowerment, social inclusion, and improve household food security and nutrition, especially for children (Bjerge, Torm, & Trifkovic, 2021; Blattman, Green, Annan, & Jamison, 2013).

However, a comparative analysis of the four countries reveals significant variations in the impact of training, highlighting the influence of economic, social, ecological, cultural, and political contexts (Irwin, Flaherty, & Carolsfeld, 2021). Many contextual factors could explain these variations, among which are differences in households' consumption patterns, income from fisheries-related activities, and the degree of women's autonomy over this income to purchase complementary foods for a quality diet. Future studies are encouraged to further explore the underlying mechanism of these heterogeneities. Impact of training on food security is statistically significant in Sierra Leone and Tanzania, while dietary quality gains were most significant in Ghana and Malawi. Incomes of trained women were notably higher in Ghana and Malawi, though the results for Tanzania and Sierra Leone were not statistically significant.

The transmission channels analysis indicates that women's training impacts household food consumption through increased fish consumption and higher income from SSF activities. These findings align with previous research, highlighting improved access to livestock-based foods and greater involvement in financial and dietary decisions (Adu, Kuwornu, Anim-Somuah, & Sasaki, 2018). However, the heterogenous results across the four countries and these transmission channels highlight the need for the training programmes to emphasize complementarity between household fish consumption and balanced dietary spending of fisheries-related income. Higher income from fisheries improves food security by increasing purchasing power for diverse foods, reducing vulnerability to hunger. However, if income is spent on non-food needs or low-nutrient staples, dietary quality may remain poor. Conversely, regular fish consumption directly enhances dietary quality by providing essential nutrients (protein, omega-3, vitamins). However, relying mainly on fish with limited complementary foods (e.g., vegetables, grains) can lead to nutrient deficiencies, impacting overall diet quality despite food security.

This study recommends that the FAO and its development partners collaborate with national governments to tailor training programs to country-specific contexts. The programs should focus on enhancing market access, promoting income diversification through small-scale agriculture and alternative livelihoods, and empowering women to generate income for better access to nutritious food. In Sierra Leone and Tanzania, the focus should be on nutrition education and financial management for nutrition, encouraging households to allocate income toward nutrient-rich foods. In Ghana and Malawi, the emphasis should be on improving fish distribution efficiency and storage techniques to reduce post-harvest losses, stabilize supply, and strengthen financial resilience, ultimately enhancing food security.

Note

1. It is worth mentioning that the survey was carried out during the outbreak and rapid spread of the COVID-19 pandemic. Consequently, the likely effects of the pandemic on some of our estimates cannot be ruled out.

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Author contributions

CRediT: **Emmanuel Orkoh**: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing; **Assem**

Abu Hatab: Conceptualization, Investigation, Project administration, Supervision, Validation, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are openly available in the Microdata catalogue of the Food and Agricultural Organization (FAO) at https://microdata.fao.org/index.php/catalog/2519, but the codes for the analysis are available from the authors on request.

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Appendix A

Table A1. Summary of sample sizes across all five countries

Country	Ghana	Malawi	Sierra Leone	Tanzania	Uganda	Total
Individuals	296	306	431	281	300	1,614
Focus group discussions	40	11	31	11	10	103
Key informant interviews	7	10	10	18	10	55

Source: adapted from (FAO, 2023a).

Table A2. Compare-mean tests of training in SSF and household food security index (by country)

	Combined	Participants	Non-participants	Difference
Full sample	38.973	43.449	37.014	6.435***
	(1.001)	(1.935)	(1.158)	(2.168)
Ghana	56.698	58.645	55.226	3.420
	(2.222)	(3.406)	(2.936)	(4.491)
Tanzania	31.205	46.226	27.635	18.592***
	(2.029)	(5.201)	(2.122)	(5.028)
Malawi	47.958	51.724	47.077	4.648
	(1.891)	(4.667)	(2.063)	(4.825)
Sierra Leone	23.248	25.440	21.889	3.552
	(1.374)	(2.522)	(1.582)	(2.825)

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
Source: Authors' computation based on FAO (2023a).

Table A3. Compare-mean tests of training in SSF and household dietary quality index (by country)

	Combined	Participants	Non-participants	Difference
Full sample	43.932	45.797	43.113	2.684***
	(0.509)	(0.967)	(0.595)	(1.104)
Ghana	51.570	54.331	49.444	4.886***
	(1.003)	(1.545)	(1.298)	(2.006)
Tanzania	47.793	49.743	47.330	2.413**
	(1.006)	(2.266)	(1.122)	(2.554)
Malawi	55.263	57.700	54.701	2.999**
	(0. 948)	(2.250)	(1.043)	(2.425)
Sierra Leone	36.875	37.530	36.463	1.067
	(1.055)	(1.622)	(1.385)	(2.170)

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
Source: Authors' computation based on FAO (2023a).

Table A4. Compare-mean tests of training by fisheries-related income (by country)

	Combined	Participants	Non-participants	Difference
Full sample	119.799	145.858	108.597	37.261***
	(6.426)	(17.482)	(5.252)	(13.980)
Ghana	153.847	172.324	139.879	32.444*
	(11.611)	(17.257)	(15.627)	(23.414)
Tanzania	62.426	66.489	61.461	5.028
	(4.434)	(15.114)	(4.168)	(11.268)
Malawi	168.508	204.525	160.085	44.440**
	(10.910)	(27.433)	(11.799)	(27.764)
Sierra Leone	94.269	126.629	75.056	51.573*
	(16.908)	(43.615)	(7.368)	(34.912)

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
Source: Authors' computation based on FAO (2023a).

Table A5. Impact of women's training in SSF value chains on household fish consumption

	Inverse probability weighted estimators				Matching estimators	
Dependent variable (household fish consumption)	RA	AIPW	IPW (linear)	IPW (weighted mean)	PSM	NNM
ATE—Training	0.393***	0.392***	0.392***	0.391***	0.056	0.070
	(0.109)	(0.109)	(0.109)	(0.109)	(0.141)	(0.124)
PO mean	5.627***	5.628***	5.628***	5.628***		
	(0.065)	(0.065)	(0.065)	(0.065)		
Observations	1,242	1,242	1,242	1,242	1,196	1,196
Tebalance test (*p*-value)	0.292	0.292	0.292	0.292		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
AIPW: augmented IPW; NNM: nearest neighbourhood matching; PSM: propensity score matching; RA: regression adjustment.
Source: Authors' computation based on FAO (2023a).

Table A6. Fisheries-related income and household food security and dietary quality

	Food security			Dietary quality		
Dependent variables	OLS	Tobit		OLS	Tobit	
Food security and dietary quality	Coeff.	Coeff.	Marginal effect	Coeff.	Coeff.	Marginal effect
Income (log)	5.873***	6.693***	5.219***	1.693***	1.669***	1.657**
	(0.926)	(1.125)	(0.874)	(0.508)	(0.476)	(0.473)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,174	1,174	1,174	1,159	1,159	1,159
R-squared	0.233			0.167		

Note: Robust standard errors in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
Source: Authors' computation based on FAO (2023a).