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Enhancing women's empowerment and climate- adaptive capacities in aquaculture in climate hotspots in Zambia

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COVER PHOTO: Maggie Chishala and Hendrix Chishala in Luwingu, northern Zambia. Credit: Chosa Mweemba.

ABOUT CGIAR GENDER IMPACT PLATFORM

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Abstract

Aquaculture, the farming of aquatic organisms like fish, is crucial for food security, income and employment in sub-Saharan Africa. However, gender inequalities hinder women's agency and climate-adaptive capacities in this sector. Women often face limited access to productive assets and climate-smart technologies and experience restrictive social norms. These constraints result in gendered divisions of labor, inequitable benefit distribution and disparities in resource access and power within the aquaculture value chain. Climate change affects water quality, fish health and overall production, thereby posing economic challenges to communities that rely on aquaculture and exacerbating gender inequalities.

This study explores whether addressing gender constraints in aquaculture can enhance women's empowerment and climate-adaptive capacities. The study uses a mixed-methods quasi-experimental design and draws on primary data collected in October 2022 in Northern and Luapula provinces, climate change hotspots where gender equality and climate-adaptive capacities are acutely challenged. It examines the extent to which gender-intentional and gender-responsive aquaculture interventions by WorldFish in Zambia that address some of these constraints—such as women's limited agency and limited access to technology, information and knowledge—are associated with women's empowerment, better food and nutrition outcomes and enhanced climate-adaptive capacities. The research additionally compares project-level Women's Empowerment in Agriculture Index (pro-WEAI) measures between treatment and control groups.

Findings reveal a positive relationship between these interventions and women's access to aquaculture information, involvement in decision-making, adoption of climate-smart practices, and improved food security. However, a weak negative relationship is noted regarding women's control over fishpond income. Qualitative insights emphasize the importance of women role models and of cooperatives to improve access to land as well as the challenges of gendered roles in control of resources and in decision-making.

Keywords: *aquaculture, women's empowerment, climate, adaptive capacity, dietary diversity, propensity score matching, ex-post impact assessment*

1. Introduction

Aquaculture, the farming of aquatic organisms such as fish and other aquatic species, plays a key role in addressing food insecurity, providing a source of income and offering employment opportunities in many contexts, particularly in sub-Saharan Africa (Kawarazuka 2010; Kassam & Dorward 2017; Filipski & Belton 2018).

Important gender inequalities exist in aquaculture. In many contexts, women fish farmers' agency and climate-adaptive capacities are limited compared to their men counterparts. They often lack access to and control over productive assets, such as land for fishponds, and have limited access to climate-smart technologies and approaches due to constraining social norms and gender roles. The constraints to gender equality can be seen in the gendered division of labor, distribution of benefits, access to and control over assets and resources, access to social and institutional networks, and power relations in the aquaculture and fish farming value chain (IFAD 2016; Kruijssen et al. 2018).

Aquaculture is susceptible to the impacts of climate change because climate variability, particularly water temperature changes, affects water quality and fish health. Climate change affects "the seasonality of particular biological processes, altering marine and freshwater food webs, with unpredictable consequences for fish production" (Cochrane & Garcia 2009). According to Braimoh et al. (2018), climate change will likely lead to fluctuations in fish stocks and cause significant economic challenges for many vulnerable communities and nations that depend on fisheries and aquaculture. Gender inequalities are likely to exacerbate the impacts of climate change on women by restricting their participation in and benefits from engaging in aquaculture, further constraining their potential to build a valued livelihood from aquaculture (Awiti 2022; IFAD 2016). Climate change impacts can also intensify gender inequalities because of their gendered effects and because climate coping and adaptive capacities are gendered (Mapedza et al. 2023; Tirado et al. 2015).

This study tests hypotheses—derived from conceptual frameworks—(i) that illustrate the gendered aspects of agrifood systems and the relationship between gender equality and climate change, and (ii) that highlight how addressing structural constraints to gender equality in agrifood systems within climate-affected contexts can contribute to women's empowerment and gender equality and more gender-equal adaptive capacities. We test these hypotheses for the case of aquaculture in climate-affected areas in Zambia. To test these hypotheses, we use a mixed-methods quasi-experimental research design to examine the extent to which gender-intentional and gender-responsive aquaculture interventions implemented by WorldFish in Zambia that address some of these constraints—such as women's limited agency and limited access to technology, information and knowledge—are associated with women's empowerment, better food and nutrition outcomes and enhanced climate-adaptive capacities. The study locations are Northern and Luapula provinces in Zambia, which have been identified as climate-agricultural-gender inequality hotspots, meaning they are vulnerable to the impacts of climate change, and gender equality and climate-adaptive capacities are acutely challenged (Lecoutere et al. 2023). We rely on primary quantitative gender-disaggregated intrahousehold data and qualitative data collected in October 2022 in fish farming households in treatment districts in the two provinces where gender-responsive aquaculture interventions were implemented and in control districts without such interventions. We additionally compare population-level and project-level Women's Empowerment in Agriculture Index (pro-WEAI) measures between the treatment and control groups.

In this paper, we first describe the context and interventions, then continue with the conceptual framework and research hypothesis. This is followed by a description of the methods, after which we present the quantitative and qualitative results. We end with discussion of this study's findings.

2. Context

2.1 Aquaculture in Zambian climate and gender inequality hotspots

This study focuses on Zambia's Northern and Luapula provinces, which are climate–agricultural–gender inequality hotspots. It is estimated that over 80 percent of Zambians rely on agriculture as a livelihood (IFAD 2016). Agriculture is primarily rainfed, making it vulnerable to weather variability due to climate change impacts. The two provinces contain most of Zambia's water bodies. They are the hub for fisheries and aquaculture (Nyangu 2016). Hosting 33.9 percent of the 9,615 smallholder fish farming households nationally, Northern and Luapula provinces have the country's largest smallholder fish farmers population (Central Statistical Office 2019).

Northern and Luapula provinces have been affected by climate-related extreme weather events such as floods, rising temperatures and unpredictable rainfall patterns (Ministry of Gender for the Republic of Zambia 2016). These climatic hazards have adversely impacted food and water security, water quality and livelihoods of the people, especially in rural communities' dependent more on aquatic food systems (Zambia Ministry of Fisheries and Livestock 2014). Although these areas receive the highest average rainfall, erratic rainfall and increased temperatures have also occurred in the region. Further, although excess rainfall occurs more frequently than drought in this area, the impacts of droughts are graver. Among the areas most affected by extreme weather events is Luapula Province with seven rainfall-deficit years and seven excess-rainfall years (of the 35 years between 1981/82 and 2016/17) (Brimoh et al. 2018). A recent study on the effects of climate change on aquaculture in Zambia revealed that climate variability, including erratic rainfall and rising temperatures, has drastically affected water availability and quality, leading to increased fish mortality and lower productivity in ponds. More specifically, in Northern and Luapula provinces, the majority of aquaculture producers included in the study agreed that high frequency of drought and rise in temperature are effects of climate change, and about half the aquaculture producers agreed that high frequency of flooding is a climate change effect (Maulu et al. 2024). A study focusing on Lake Bangweulu, the system of five interconnected lakes which is shared by the Luapula, Northern, Muchinga and Central provinces, showed that higher temperatures, reduced rainfall and lower water levels negatively affect fish populations on the Luapula province side (Ng'onga et al. 2019). With the frequency and intensity of climate events expected to rise, the negative impact on people's livelihoods, food security, nutrition and household income generation will likely increase unless remediation interventions are implemented.

Even if women may not be registered or perceived as fish farmers, both men and women are heavily engaged in fish production at the farm level. Women are mainly involved in value-adding, that is, drying and processing fish (Kruijssen et al. 2018). Women's involvement is determined by their gendered role as family caregivers, limiting their mobility to engage in activities far from the home. As women also lack access to credit and other resources, they may work as fish traders because it requires a lower capital injection than fishing or fish farming (Béné and Merten 2008). These gendered inequalities in opportunities in aquaculture and fish farming are based on attitudes, beliefs, practices and "rules" determined by social institutions that relegate women to participating in fish value chain nodes and activities with lower returns (Weeratunge and Snyder 2009).

Effects of climate change on aquaculture in Zambia disproportionately affect women. For example, women in Zambia's Northern Province face intensified climate change challenges due to limited access to financial resources and climate-smart information, which restricts their ability to implement effective adaptation strategies (Vogel et al. 2023). Additionally, women often lack access to productive resources—such as land, capital and climate-smart aquaculture technologies—due to gender-based barriers, making them less equipped to adapt to climate-induced stresses (Kruijssen et al. 2018; Vogel et al. 2023).

2.2 The interventions

Since 2018, WorldFish Zambia has implemented several interventions in the Luapula and Northern provinces of Zambia to foster equitable, sustainable, productive and climate-resilient aquatic food systems. The interventions revolved around promoting better management practices so aquaculture smallholder farmers would become more resilient. Skills such as how to site a pond, using resilient seed, fish health management, biosecurity and feed management were promoted. Two of these interventions are relevant to this study: the Aquaculture Technical, Vocational, and Entrepreneurship Training for Improved Private Sector and Smallholder Skills (AQ TEVET) project and the Piloting Inclusive Business and Entrepreneurial Models [IBEMs] for Smallholder Fish Farmers and Poor Value Chain Actors project (which was piloted in Malawi as well as in Zambia). The projects used 'soft' farmer-oriented technologies and methods (e.g., improved fish-farming practices) to improve farm productivity, rather than physical infrastructure or technologies.

These WorldFish interventions were designed to reduce the barriers between smallholder aquaculture farmers and their access to improved aquaculture practices, inputs (feeds and seeds) and output (markets chains) in Zambia's aquaculture value chain and food systems. Activities under these projects included small-scale farmer training (such as demonstrations and training manuals), supporting and equipping small and medium-sized enterprises (SMEs) in the aquaculture value chain and establishing innovation platforms.

First, the AQ TEVET project sought to increase the number of smallholder commercial fish farmers with enhanced aquaculture knowledge and up-to-date practical skills to help sustainably grow the sector and make it more inclusive. It did this by supporting fish farmers with market opportunities and extension support services and linking them to input and output markets within the aquaculture value chain. The AQ TEVET project aimed to have 40 percent of its beneficiaries be women. It ensured gender integration by working with women cooperatives, getting women to host demonstration plots, involving women in experiments, coaching and mentoring women and working with traditional leaders to provide land to women's fish cooperatives, upgrading the fisheries and aquaculture curriculum at the Natural Resources Development College in Zambia and encouraging women to apply to study fisheries science. The project also incentivized women fish farmers by offering them subsidized fingerlings and commercial feeds.

Second, the IBEMs intervention was designed to establish inclusive business and entrepreneurial models that provide sustainable access to fish for smallholder fish farmers; enhance fish seed, feed and knowledge; and support productivity and profitability. The objective was also to increase consumers' access to fish for enhanced nutrition.

Building on lessons learned on gender from the AQ TEVET project, the IBEMs intervention sought to pilot scalable, pro-poor and gender- and youth-inclusive business and entrepreneurial models. These models are intended to circumvent existing market failures and inefficiencies to successfully integrate poor women, men and youth, either on the demand side as clients or on the supply side as distributors, suppliers of goods and services or employees (Rösler et al. 2013). The IBEMs intervention ensured that IBEMs participants and their spouses were trained in business and entrepreneurship and mentored and coached on better management practices. The project team used a household approach to mentor and coach all selected IBEMs participants to address the gender gaps they identified. Wives of selected IBEMs participants and their young adult children actively participated in hatchery activities and training. For feed operators, the project selected SMEs and individuals demonstrating close collaboration between the husband and wife in managing the business.

As part of the Trainer of Trainers program, IBEMs participants were trained in gender integration, particularly on why it was necessary to integrate gender into their work, especially when training and recruiting training participants. The IBEMs participants were trained to use adult-training methods to ensure that people with low levels of education, primarily women, could understand the training. Aquaculture training seminars were conducted to incorporate women into fish farming activities to foster better gender-integrated business

strategies. This approach sought to consider gender in all stages of development, assess the implications of any planned action on gender equity and raise awareness of the critical role of women in fish farming. Two IBEMs offered fish offtake services, which entailed buying fish produced by both women and men fish farmers at competitive prices. The IBEMs intervention also hosted meetings between SMEs, farmers and finance institutions, including microfinance institutions and the Citizenships Economic Empowerment Commission (CEEC)—a government program supporting economic empowerment—to provide credit to farmers and SMEs. Three IBEMs participants received funds from the CEEC, but none of them were women.

Both projects used training materials in the local language, to make them more accessible to women with low levels of education, and collected and analyzed sex-disaggregated data. The projects also invited women as guest speakers on local radio programs about aquaculture and encouraged SMEs to promote the participation of women and youth in training and extension. Some SMEs worked with traditional authorities to lobby for women interested in aquaculture being allocated land to set up fish farming ponds, either as individuals or as part of cooperatives.

While the innovations and interventions attracted more women into aquaculture, the target of having 40–50 percent women as project beneficiaries was not reached. This was because women did not always meet all the criteria for inclusion, mainly those related to cofinancing in the case of feed operators and related to pond ownership in the case of hatchery operators. In two cases, despite being selected, candidate women hatchery operators opted not to participate in the intervention. Women were targeted with training on better management practices of aquaculture and were mentored and coached by IBEMs to implement these practices on their farms.

3. Conceptual framework and hypothesis

We adopt the Gendered Food Systems Framework by Njuki et al. (2022), developed for the United Nations Food Systems Summit 2021, as the conceptual framework. The framework sets out that engagement in and outcomes of food systems—such as dietary, economic, livelihood and environmental impacts, along with gender equality and women’s empowerment—are shaped by the influence of gendered drivers of food systems and structural gender inequalities that can be formal or informal and individual or systemic in nature (Figure 1). These structural gender inequalities relate to agency, access to and control over resources; gendered social norms and policies; and institutions and governance (the dark gray ‘quadrant’ in Figure 1). For a comprehensive review of the evidence on these pathways and mediating factors, see Njuki et al. (2022). Conceptual frameworks and research particularly focusing on the relationship between gender equality and climate change in agrifood systems posit that gendered coping, adaptive and resilience capacities are influenced by the same structural inequalities related to agency, resources, norms and governance (Bryan et al. 2023; Kristjanson et al. 2017).

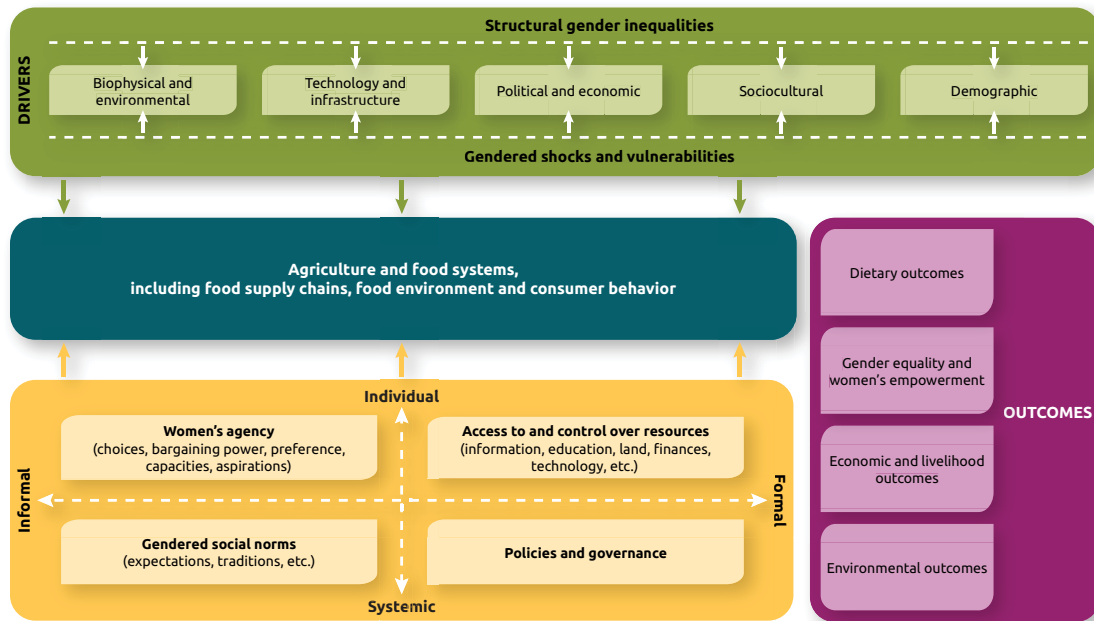


Figure 1. Gendered Food Systems Framework. Source: Adapted from Njuki et al. (2022)

This study tests hypotheses derived from the Gendered Food Systems Framework and the frameworks linking gender equality and climate change by studying gender-intentional and gender-responsive aquaculture interventions implemented in climate-affected aquaculture-based food systems. The focus is on understanding the effects of addressing structural constraints to gender equality—in particular women’s limited access to and control over resources and restricted agency—on participation in agrifood value chains and food system outcomes, such as empowerment, climate-adaptive capacities, and nutrition, and the gender equality thereof.

The research hypotheses are that addressing gender inequality in access to technology, information and knowledge relevant for aquaculture, as well as gender inequality in agency and roles in aquaculture, will be positively associated with (1) women’s involvement in aquaculture and access to and control over resources for and information about aquaculture (research hypothesis *RH1*), (2) women’s empowerment in aquaculture (*RH2*), (3) women’s awareness, knowledge and adoption of climate-smart aquaculture practices (*RH3*), and (4) food and nutrition outcomes (which are further down the impact pathway presented in the Gendered Food Systems Framework) (*RH4*).

In this study context where women are generally less involved and less empowered, have more limited adaptive capacities and benefit less from aquaculture than men, we take that improvements in outcomes for women imply enhanced gender equality. Thus, the specific research hypotheses of this study pertain to whether and to what extent participation in the gender-intentional and gender-responsive aquaculture interventions, as implemented by WorldFish in Northern and Luapula provinces in Zambia, are positively associated with (1) women’s involvement in aquaculture and their access to and control over resources for and information on aquaculture, (2) women’s empowerment in aquaculture, (3) women’s awareness, knowledge and adoption of climate-smart aquaculture practices, and (4) household food security and women’s diet diversity.

4. Methods

4.1 Data

Data was collected between October 2022 and May 2023. This study utilized a multi-staged sampling technique. Districts and households were purposively sampled based on the availability of fish farming production potential and the implementation of WorldFish interventions. Seven districts across the two provinces (with 24 districts in total) where WorldFish interventions had been implemented were selected as treatment districts. Five districts across the two provinces (of the 12 districts) that did not receive any WorldFish intervention were selected as control districts.

The study used stratified sampling to put all project beneficiaries in the treatment districts into two strata: smallholder fish farmer households (treatment and control groups) and SME owners such as feed and hatchery operators. It allowed the study team to divide the sampling frame into homogenous and nonoverlapping subgroups and to draw samples in each stratum.

Farming households from the sampled treatment districts were selected based on the criteria that they should (1) have a stocked fishpond(s), (2) have participated in training offered through WorldFish projects, and (3) have harvested fish in the last 12 months. From 1,680 WorldFish-registered fish farming households, a sample size of 322 smallholder fish farming households was drawn (see [Table 1](#) for a description of the sample). The sampling criteria for farming households in the control districts were (1) having stocked fishpond(s), and (2) having harvested fish in the last 12 months. The sample from control districts was of 178 households.

We collected gender-disaggregated intrahousehold data by individually interviewing women and men in the household (above 18 years of age) in the treatment and control districts. The two adult household members (woman and man) may or may not have been a married couple (although most of them were married or co-habiting). In households where the woman and man were not a married couple, the eldest woman and man were interviewed.

Table 1. Sample sizes

Type	Province	District	Respondents	Household
Treatment	Northern	Mungwi	120	60
		Luwingu	174	87
		Mbala	68	34
		Mporokoso	84	42
		Kasama	40	20
	Luapula	Mansa	64	32
		Kawambwa	94	47
Total	7	644	322	
Control	Northern	Kaputa	68	34
	Luapula	Chembe	22	11
		Mwense	64	32
		Mwansabomwe	32	16
		Nchelenge	170	85
Total	5	356	178	

Data was collected using an individual survey. Information on women’s empowerment was collected using the pro-WEAI tool. Other data includes participation in aquaculture and aquaculture interventions; access to aquaculture-related resources; awareness, knowledge and adoption of climate-smart aquaculture practices; dietary diversity and food insecurity. Descriptive statistics of respondents’ socio-demographic characteristics can be found in [Appendix 1](#).

4.2 Outcome indicators

We defined 11 outcome indicators, each relating to one of the four research hypotheses ([Table 2](#); descriptive statistics of outcome indicators are in [Appendix 1](#)). In line with other studies, both enhanced individual and joint decision-making and resource access are considered empowering (Malapit et al. 2019). Acknowledging that there are gender differences in perception and reporting in surveys—for example, in perceptions and reporting a jointly made decision (Acosta et al. 2020)—the indicators are based on women’s responses to capture women’s perspectives on their involvement, empowerment and diet outcomes.

In what follows we discuss how each indicator is defined and operationalized.

Table 2. Outcome indicators

Research hypothesis	Outcome indicators (Y)
Involvement of women in aquaculture and increased access to and control over resources for and information on aquaculture	Y1 = Women’s involvement in aquaculture Y2 = Women’s involvement in control over the productive resources (land) for aquaculture Y3 = Women’s involvement in ownership of land for fishpond construction Y4 = Women’s access to information on aquaculture
Women’s empowerment in aquaculture	Y5 = Women’s involvement in aquaculture-related decision-making Y6 = Women’s control over income from fishpond culture
Women’s awareness, knowledge and adoption of climate-smart aquaculture practices	Y7 = Women’s awareness of aquaculture-related climate-smart practices Y8 = Women’s knowledge of aquaculture-related climate-smart practices Y9 = Women’s adoption of aquaculture-related climate-smart practices
Agrifood system outcomes related to food and nutrition security	Y10 = Women’s Dietary Diversity Score (WDDS) Y11 = Food Insecurity Experience Scale (FIES) based on women’s responses

More detail about each indicator is given here:

- Y1 = Women’s involvement in aquaculture: This indicator is a dummy variable taking the value 1 if the woman respondent of the fish farming household owns an active fishpond, either alone or jointly with her husband (and also makes decisions about the fishpond as the owner); the value 0 otherwise.
- Y2 = Women’s involvement in control over the productive resources (land) for aquaculture. This is a dummy variable taking the value 1 if the woman respondent has control over the productive resources for aquaculture, either alone or jointly with her husband; the value 0 otherwise. Respondents were asked if they own any of the land owned or cultivated by the household.

- Y3 = Women's involvement in ownership of land for fishpond construction. This is a dummy variable taking the value 1 if the woman respondent owns land for fishpond construction, either alone or jointly with her husband; the value 0 otherwise.
- Y4 = Women's access to information on aquaculture. This is a dummy variable taking the value 1 if the woman respondent received training on pond construction or on integrated aquaculture or climate-smart aquaculture; the value 0 otherwise.
- Y5 = Women's involvement in aquaculture-related decision-making related to integrating aquaculture with crops, integrating aquaculture with livestock, improved pond construction, water harvesting and improved storage. This is a dummy variable taking the value 1 if the woman respondent is involved in any of the decisions that relate to aquaculture and fishpond culture, either alone or jointly with her husband; the value 0 otherwise.
- Y6 = Women's control over income from fishpond culture. This is a dummy variable taking the value 1 if the woman respondent has control over the income from fishpond culture, through input into decisions either alone or jointly with her husband; the value 0 otherwise.
- Y7 = Women's awareness of aquaculture-related climate-smart practices. This is a dummy variable taking the value 1 if the woman respondent is aware of any of the following five aquaculture-related climate-smart practices: (1) integrated aquaculture with crops, (2) integrated aquaculture with livestock (goat, sheep, cattle, poultry), (3) improved pond construction, (4) water harvesting, and (5) improved grain storage; the value 0 otherwise.
- Y8 = Women's knowledge of aquaculture-related climate-smart practices. This is a dummy variable taking the value 1 if the woman respondent received training on integrated aquaculture or climate-smart aquaculture or had access to climate information services; the value 0 otherwise.
- Y9 = Women's adoption of aquaculture-related climate-smart practices. This is a dummy variable taking the value 1 if the woman respondent used any of the following five aquaculture-related climate-smart practices over the course of 12 months prior to data collection: (1) integrated aquaculture with crops, (2) integrated aquaculture with livestock (goat, sheep, cattle, poultry), (3) improved pond construction, (4) water harvesting, and (5) improved grain storage; the value 0 otherwise.
- Y10 = Women's Dietary Diversity Score (WDDS). This indicator is the WDDS of the woman respondent calculated according to FAO guidelines (FAO 2011). It measures the number of food groups the respondent reports to have consumed in the 24 hours prior to data collection. We enquired about nine food groups needed to create the WDDS as outlined in FAO (2011): starchy staples; dark-green leafy vegetables; other vitamin-rich fruits and vegetables; other fruits and vegetables; organ meat; meat and fish; eggs; legumes, nuts and seeds; and milk and milk products. The food groups in WDDS put emphasis on micronutrient intake. Increasing values of WDDS indicate higher diet diversity, with 9 as the highest diet diversity score (FAO 2011, 25).
- Y11 = Food Insecurity Experience Scale (FIES) based on women's responses. This indicator captures self-reported experiences and behavior that relate to difficulties in accessing food due to constrained resources (FAO 2018). The indicator is based on eight survey questions about food access in the year prior to data collection.¹ The FIES score is constructed using the total number of affirmative answers to the eight questions, with higher values indicating higher food insecurity.

¹ The eight FIES questions are: During the last 12 months, was there a time when, because of lack of money or other resources: You were worried you would not have enough food to eat?; You were unable to eat healthy and nutritious food?; You ate only a few kinds of foods?; You had to skip a meal?; You ate less than you thought you should?; Your household ran out of food?; You were hungry but did not eat?; You went without eating for a whole day?

4.3 Analysis and identification method

To examine the relationship between the gender-intentional and gender-responsive aquaculture interventions and women's involvement, empowerment and adaptive capacities in aquaculture, we estimated the average treatment effect (ATE) of the interventions on the various outcome indicators using equation 1. Our unit of analysis i is the woman who is the co-head of the fish farming or SME owner households.

$$Y = \alpha + \beta T_i + \varepsilon_i \quad (\text{Equation 1})$$

With Y the outcome of interest, T a binary treatment variable taking the value 1 if the respondent is part of the treatment group and 0 otherwise, α a constant, and ε the error term. The coefficient of interest is β , the estimated ATE.

We adopted a quasi-experimental method as the identification method and estimated the ATE using 2:1 nearest neighbor Propensity Score Matching (PSM).²

As the basis for matching on propensity scores, we relied on variables that relate to treatment assignment and the outcome of interest but are unlikely to have been directly affected by the gender-intentional and gender-responsive aquaculture interventions (the treatment). These include socio-demographic characteristics and asset ownership of the households.³

The statistical balance before and after matching for the ATE estimations for each outcome variable is presented in [Appendixes 3 to 13](#). For each outcome variable, balance improved with matching in most of the matching variables. However, some imbalance may remain after matching, in particular for characteristics such as proportion of women in the household, ownership of cell phone(s), non-mechanized farm equipment, or irrigation equipment.

We acknowledge the limitation of PSM in ruling out selection bias since the method relies on unverifiable assumptions that unobserved differences between the treatment and control groups are absorbed by matching on observable characteristics (Rosenbaum and Rubin 1985). Therefore, we acknowledge that care should be taken when inferring causal relationships from the results. While areas with and without interventions are faced with similar agro-ecological and socioeconomic conditions, we cannot fully rule out differences in trends. Spillovers between areas with and without interventions are unlikely, given the geographic distance, but cannot be ruled out entirely.

As we test multiple hypotheses, the risk of type I errors may have increased. Therefore, we calculated False Discovery Rate (FDR) q -values to correct p -values for multiple hypothesis testing, applying the method by McKenzie (2020).

² PSM is a widely used approach to estimate the causal effect of interventions in ex-post quasi-experimental studies and in the absence of appropriate instrumental variables. It seeks to mimic the randomised assignment of units to treatment and comparison groups by selecting units for the comparison group that share traits with the treatment group's unit (Gertler et al. 2016). The general idea is to construct a comparison group from a sample of non-participants that "resembles" the participants based on observable characteristics.

The propensity score is a one-dimensional summary that represents the probability of receiving the treatment based on the estimated probability of participating in the intervention based on observable characteristics. The internal validity of the PSM technique depends on the capacity of the model to consider all the factors determining participation in the intervention through the included observable characteristics and under condition of sufficient overlap in the propensity score distribution between the treatment and control groups.

³ The matching variables are based on the responses of the women co-heads and are distance to market, income, household size, proportion of women in household, household ownership of land, large livestock, small livestock, poultry and other small animals, fishpond or fishing equipment, non-mechanized farm equipment, non-farm business equipment, house or building, large consumer durables (e.g., TV), small consumer durables (e.g., radio), cell phones, other land not used for agricultural purposes, means of transportation, pond-construction equipment, irrigation equipment, fish-harvesting equipment, fish-processing equipment and fish-storage equipment. Descriptive statistics of matching variables can be found in [Appendix 2](#).

4.4 The project-level Women's Empowerment in Agriculture Index

We additionally compared population-level indicators of women's empowerment for the treatment and control groups using pro-WEAI. We compared the pro-WEAI indices without using an identification method.

Pro-WEAI is rooted in the empowerment framework by Kabeer (1999), which looks at empowerment as a change process in the interrelated dimensions of resources agency and accomplishments (achievements). The framework emphasizes measuring people's capacity to make strategic decisions that affect their lives. The study adopted the Three Domains of Empowerment Index (3DE) of pro-WEAI, which demonstrate different types of agencies: intrinsic agency (power within), instrumental agency (power to) and collective agency (power with) (Table 3). The data for the types of agency is collected through 10 indicators in the pro-WEAI tool.

As a first step, each individual's empowerment score is calculated (i.e., the percentage of indicators in which the person has achieved adequacy). A person is considered empowered if they achieve adequacy in 80 percent of the indicators. The pro-WEAI is calculated as the weighted mean of two subindices, the 3DE for women (weight of 90 percent) and the Gender Parity Index (GPI) score (weight of 10 percent) (Alkire et al. 2013; Malapit et al. 2019; Seymour et al. 2023). Improvements in either the 3DE or GPI will increase pro-WEAI scores. The 3DE for women is the sum of the percentage of women who are empowered and the mean empowerment score of disempowered women weighted by the percentage of women who are disempowered. The GPI is a household-level index; it reflects the prevalence and depth of gender parity in the sample. It is calculated by subtracting the product of the percentage of households with gender parity and the mean empowerment gap from 1. A household has gender parity if the woman is empowered, and her empowerment score is at least equal to that of her husband/partner. The mean empowerment gap reflects the average difference between the empowerment scores of the man and woman in households that do not achieve gender parity.

We also visualize the contributions of each indicator to total disempowerment in each of the subsamples of women and men in the treatment and control groups. Total disempowerment is the complement to 1 of 3DE ($1 - 3DE$). The contributions reflect the percentage of respondents who are both disempowered and inadequate in the indicator.

Table 3. Pro-WEAI domains

Agency	Indicators
Intrinsic (Power within) (3 indicators)	<p>Attitudes against partner violence against women: This indicator captures respondents' views on partner violence and provides the common norms and attitudes toward husbands beating their wives.</p> <p>Self-efficacy: This indicator captures a person's confidence in their ability to accomplish tasks or succeed in certain situations.</p> <p>Autonomy in income: This indicator measures autonomy in decision-making about the use of income generated from agricultural and non-agricultural activities. It provides a measure of internal and external factors that influence the respondent's decision concerning the use of income.</p>
Instrumental (Power to) (6 indicators)	<p>Input in livelihood decisions: This indicator captures whether respondents have adequate participation in certain types of agricultural and work activities and in making decisions on various aspects of household life. A respondent is considered adequate in input in livelihood decisions if they participate in at least one activity and they have input into some, most or all decisions for each of the activities they participate in, or they feel they could make the decision to a medium extent if they wanted to (Seymour et al. 2023). An example of the activity is staple grain farming and processing of the harvest, which refers to grains grown primarily for food consumption (rice, maize, wheat, millet).</p> <p>Ownership of land and other assets: This indicator measures the possession of land cultivated by households and other assets such as large livestock (cattle, buffaloes) and small livestock (sheep, goats, pigs).</p> <p>Control over the use of income: This indicator measures how much input the respondents have in decisions about how much of the output to keep for consumption at home rather than selling and whether the respondents have input into how income in the household is used.</p> <p>Access to and decisions on financial services: This indicator measures the household's experience with borrowing money or other items (in-kind) in the previous year from a formal lender (bank or other financial institution) and whether the respondent has access to financial services, credit and the financial accounts.</p> <p>Work balance: This indicator measures the respondent's time spent on productive activities and childcare.</p> <p>Visiting important locations: This indicator measures how often the respondents go to a public village gathering, community meeting, training for NGOs, the market or other programs and how frequently they visit these locations.</p>
Collective (Power with) (1 indicator)	<p>Group membership: This indicator measures the participation of the respondents in group activities in the community. These can be either formal or informal and customary groups.</p>

4.5 Qualitative data and analysis

We conducted key informant interviews (KIIs) with cooperatives and project staff to elicit detailed and contextual information about the project's contribution to the themes of this evaluation. These informed the choice of critical topics on which more information could be solicited in the quantitative survey and for interpreting the quantitative results (triangulation).

We conducted focus group discussions (FGDs) with smallholder farmers in treatment and control districts. Four FGDs were conducted with women only, two with men only and three with both women and men (Table 4). Additionally, seven SME owners involved in the IBEMs project were interviewed. The FGDs aimed to elicit a local understanding of empowerment and validate the survey questionnaire's domains. Like the KIIs, the FGDs and interviews provided additional information for interpreting the quantitative results.

The qualitative data (KIIs and FGDs) were collected by two (country and lead) consultants from the research team.

Table 4. Qualitative data collection

Focus group discussions		Key informant interviews	
Women only	4	Hatchery and feed operators	7
Men only	2		
Mixed	3		

Notes from FGDs and KIIs were uploaded to ATLAS.ti and MAXQDA qualitative software for coding and analysis. The data was coded according to three themes: (1) women’s access to and control of resources, (2) women’s participation in fish farming, and (3) climate-adaptive capacities among IBEMs and fish farmers. Therefore, coding followed an inductive (bottom-up) approach that allowed a narrative to emerge from the data with no preconceived notions. Data from gender-segregated FGDs was analyzed using code-document tables to compare how women and men responded to key questions. Similarly, data was disaggregated by fish farmers and SMEs owners for the same purposes.

5. Results

In this section, we discuss the quantitative and qualitative findings about the relationship between the gender-intentional and gender-responsive aquaculture interventions, as implemented by WorldFish in Northern and Luapula provinces in Zambia, and women’s involvement, empowerment, climate-adaptive capacities and nutrition outcomes in aquaculture. We first discuss the estimated ATEs, then the comparison of pro-WEAI indicators of women’s empowerment between the treatment and control groups. Lastly, we present qualitative results.

5.1 Quantitative results

We estimated the relationship between the gender-responsive aquaculture interventions and the 11 outcome indicators, which each relate to one of the four research hypotheses. The results are reported in [Table 5](#).

The first research hypothesis we address is whether, and the extent to which, the gender-responsive aquaculture interventions are associated with women’s enhanced participation in and access to and control over resources and information about aquaculture. The results only showed a statistically significant positive relationship with the likelihood of women accessing information about aquaculture. The likelihood that women in the treatment groups have this access was twice as large as that in the control group. These results support the first research hypothesis that intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture is positively related to women’s access to information about aquaculture, but not with the likelihood of women (co-)owning an active fishpond (our indicator for women’s involvement in aquaculture) nor with access to land for fishponds or productive resources for aquaculture (*RH1*).

The second research hypothesis relates to the association between the gender-responsive aquaculture interventions and women’s empowerment in aquaculture. The results showed a statistically significant relationship with women’s involvement in (sole or joint) aquaculture-related decision-making. In the control group the likelihood that women are involved in aquaculture-related decision-making was 62 percent; it was about 12 percentage points higher in the treatment group. In contrast, there was a statistically significant negative relationship between the gender-responsive aquaculture interventions and the likelihood

that women control income from fishpond culture. The magnitude of the negative coefficient was, however, relatively small (in the treatment group, the likelihood that women control income from fishpond culture was about 3 percentage points lower than in the control group, where it was 94 percent). The first finding supports the second research hypothesis of a positive relationship between intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture and women's empowerment in aquaculture (*RH2*). While the observed effect is marginal, the second finding did not support the hypothesis.

The third research hypothesis looks at the relationship between the gender-responsive aquaculture interventions and the gender equality of aquaculture-related climate-adaptive practices. The results showed a statistically significant positive relationship with women co-heads' awareness, knowledge and adoption of aquaculture-related climate-smart practices. The relative magnitude of the ATE varied. The likelihood of women being aware of aquaculture-related climate-adaptive practices of 92 percent in the control group—in the treatment group, there is a relatively small additional likelihood of 3 percentage points. The likelihood of women having gained knowledge is 14 percentage points higher in the treatment group than in the control group, where it is 37 percent. The likelihood of women having adopted aquaculture-related climate-adaptive practices is 12 percentage points higher in the treatment group than in the control group, where it is 74 percent. These results support the third research hypothesis that intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture in climate-affected aquaculture-dependent food systems is positively associated with women's climate-adaptive capacities (*RH3*).

The fourth research hypothesis revolves around the relationship between the gender-responsive aquaculture interventions and agrifood system outcomes, food security and women's diet diversity in particular. The results showed a statistically significant positive relationship with the women co-heads' individual diet diversity scores. The magnitude of the association, however, is relatively small. An average of 3.61 food groups was consumed in the control group, and women in the treatment group consumed an additional 0.21 food groups (6 percentage points difference). The Household Food Insecurity Access Scale (HFIAS) (based on the women co-heads' responses) in the treatment group was statistically significantly lower than in the control group, which implies a higher level of food security. These results support the fourth research hypothesis that there is a positive relationship between intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture and food and nutrition outcomes for households and women (*RH4*).

Table 5. Relationship between the gender-responsive aquaculture interventions and outcome variables estimated using 2:1 nearest neighbor Propensity Score Matching

	Relationship between gender-intentional and gender-responsive aquaculture interventions that intentionally challenge gendered constraints related to access to resources, agency and roles in aquaculture and ...	β (Estimated ATE)	Robust std. err.	z	P > z	FDR q-value	n Treatment	n Control	Mean in control group
RH1 The involvement of women in aquaculture and their access to and control over resources for and information on aquaculture									
Y1	Women's involvement in aquaculture	-0.011	0.036	-0.30	0.765	0.264	322	178	0.268
Y2	Women's involvement in control over the productive resources for aquaculture	-0.011	0.015	0.72	0.470	0.186	299	169	0.929
Y3	Women's involvement in ownership of land for fishpond construction	-0.027	0.054	0.520	0.606	0.223	279	159	0.761
Y4	Women's access to information on aquaculture	0.341	0.446	7.64	0.000	0.001	322	178	0.393
RH2 Women's empowerment in aquaculture									
Y5	Women's involvement in aquaculture-related decision-making	0.123	0.047	2.62	0.009	0.019	322	178	0.624
Y6	Women's control over income from fishpond culture	-0.029	0.015	1.91	0.056	0.059	320	177	0.938
RH3 Women's awarenesses, knowledge and adoption of climate-smart aquaculture practices									
Y7	Women's awareness of aquaculture-related climate-smart practices	0.034	0.173	1.98	0.047	0.059	322	178	0.916
Y8	Women's knowledge of aquaculture-related climate-smart practices	0.141	0.047	8.70	0.00	0.001	322	178	0.371
Y9	Women's adoption of aquaculture-related climate-smart practices	0.124	0.039	3.20	0.001	0.004	322	178	0.747
RH4 Agrifood system outcomes related to food and nutrition and the gender equality thereof									
Y10	Women's Individual Dietary Diversity Score (WDDS)	0.211	0.117	1.790	0.073	0.059	322	178	3.607
Y11	Food Insecurity Experience Scale (FIES) based on women's responses	-0.711	0.318	-2.23	0.025	0.037	322	178	5.652

5.2 Pro-WEAI indicators of women’s empowerment in intervention and control groups

In this section, we report the comparison of pro-WEAI indicators, the GPI and factors contributing to women’s and men’s disempowerment in the treatment and control districts. We did not use an identification method; therefore, potential selection bias is not controlled for.

The pro-WEAI related indices presented in [Table 6](#) show that the 3DE, which combines information about the prevalence of empowerment and the depth of (dis)empowerment, has a value of 0.87 for women and 0.90 for men in the treatment group. In the control group, the 3DE has a value of 0.82 for both women and men. These results suggest higher levels of empowerment among both women and men in the treatment group than in the control group (but we cannot conclude that the differences are statistically significant).⁴ The GPI, which combines information about the prevalence of gender parity and the mean empowerment gap, amounts to 0.95 in the treatment group and to 0.93 in the control group. The pro-WEAI, which combines information from the 3DE and GPI, has a value of 0.88 in the treatment group and 0.83 in the control group, suggesting higher levels of women’s empowerment in the treatment group.

Table 6. Pro-WEAI results

Indicator	Treatment		Control	
	Women	Men	Women	Men
Number of observations	322	322	178	178
Percentage achieving empowerment	65	71	58	56
Mean empowerment score of the disempowered	0.62	0.64	0.57	0.6
Three Domains of Empowerment Index (3DE)	0.87	0.90	0.82	0.82
Number of dual-adult households	311		169	
Percentage achieving gender parity	73		72	
Mean empowerment gap	0.17		0.24	
Gender Parity Index (GPI)	0.95		0.93	
Pro-WEAI	0.88		0.83	

In [Figure 2](#) we present the contributions of each indicator to total disempowerment in each of the subsamples. A first observation is the larger total disempowerment in the control group than in the treatment group, for both genders, which is in line with the differences in the 3DE values across women and men and across treatment and control groups. In the treatment group, total disempowerment is larger among women than men.

The three indicators that contribute to the largest extent to disempowerment of women in the treatment group are work balance, ownership of land and other assets, and access to and decision on financial services. These are the same in the control group. For men, work balance contributes to the largest extent to disempowerment both in the treatment and control group. This suggests that, despite lower disempowerment levels among women and men in the treatment group than in the control group, the factors that disempower women and men most are largely the same.

⁴ The pro-WEAI .do files we used did not allow for calculating standard errors; therefore, we could not run statistical tests of significance of difference.

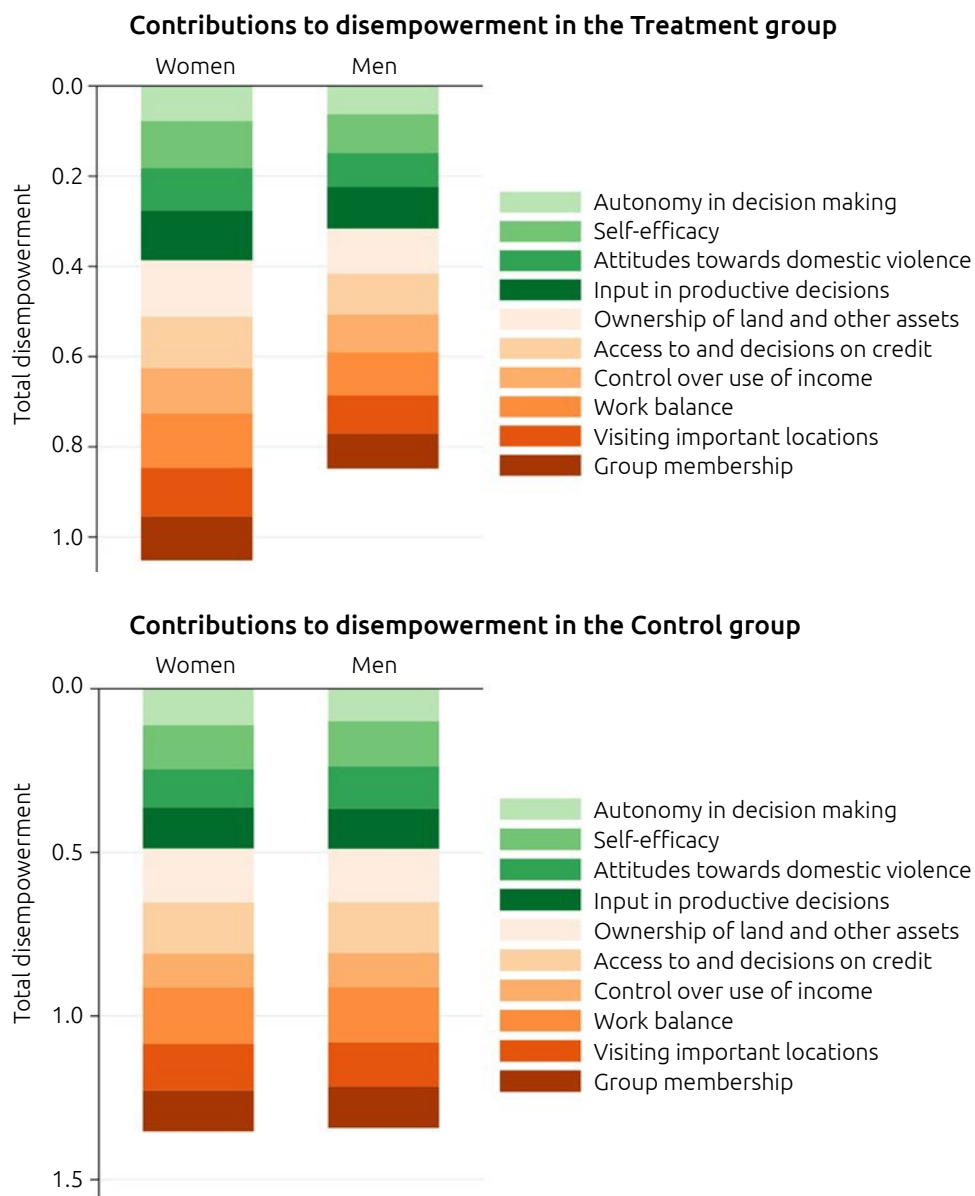


Figure 2. Contributing factors to women’s and men’s disempowerment in the treatment and control groups

5.3 Qualitative results

5.3.1 Effects of climate change

In FGDs with farmers and IBEMs participants, several adverse effects of climate change on fish farming were identified. Both women and men identified drought as the major climate change effect they experienced, followed by floods. According to the FGD respondents, the main challenge of climate change for farmers is fish mortality when ponds dry up, and fish losses when fish are washed away in floods. Men mentioned that lower water temperatures due to climate change caused fish stress, contributing to fish mortality. And, as the quote below illustrates, coping with climate change impacts is also costly:

We often experience dried fishponds and flooding, leading to high expenses, such as buying plastics to put on the pond bed. (FGD respondent, Kasakalabwe)

IBEMs participants, in particular, alluded to fish mortality or fish loss, translating into farmers buying fewer aquaculture inputs. IBEMs participants and farmers listed four key climate change adaptation strategies that they gained through support from WorldFish ([Table 7](#)).

Table 7. WorldFish provided strategies for climate change adaptation

Type of strategy	Farmers	IBEMs
Access to climate information	x	x
General training on climate change	x	
Proper site selection	x	
Livelihood diversification	x	x

5.3.2 Women’s participation in fish farming and the contribution of role models

Through their training as part of the gender-responsive aquaculture interventions, IBEMs participants have been motivated to engage with women fish farmers more strategically. The IBEMs trainees explained that their approach to engaging women farmers changed along the following lines: (1) they take more time to explain products to women who are often less informed; (2) they encourage the formation of women’s groups; (3) they actively engage with women’s groups during sales activities; and (4) they engage with customers as a couple, considering men have more control over household/family enterprises income. Women IBEMs participants in particular (5) present themselves as role models to encourage and motivate other women to engage in or expand their fish-related businesses (farming, hatchery operation, etc.).

What I am trying to do is to have one language. What a man can do, a woman can do. And at times, I make sure both partners are around when I am talking to partners. (SME owner, Kasama)

Additionally, through mobilizing around inclusion, the gender-responsive aquaculture interventions have promoted role models: women who gained access to a fishpond, managed to stock it and acquire feed have emerged as role models in their communities. The following quotes that described women as role model fish farmers came from FGD participants:

Ones who are not lazy and can work when men are away.

I have to be a responsible mother and woman and have to know what is important to me and be able to take care of myself.

A woman who is hardworking and can help and complement.

A woman who does not rely on the man. One who is independent in doing things and also supports the house. (FGD)

People see these women as encouraging other women—and even men—to engage in fish farming. According to farmers, community members can see that women are able to engage in what is considered a man’s domain. The women also illustrate the financial and other (nutritional) benefits of fish farming. Therefore, supporting women fish farming role models by WorldFish is said to have contributed to increasing the number of women and men community members involved in fish farming and to encouraging others to enhance their fish-related enterprises.

Interestingly, while both women and men community members have been encouraged by these women fish farming role models, men reported to have been motivated from the perspective that “women could not do better than them.” Women, on the other hand, have been encouraged by the opportunities to “accrue the same financial and other benefits of fish farming as these exemplary farmers.”

5.3.3 Women's access to and control over resources

The IBEMs project targeted women to provide them with access to the resources required to engage in or improve their participation in the aquaculture value chain. Interviews with IBEMs participants revealed that they have been mobilized, trained, provided with access to climate change adaptation information and linked to input and output markets. Interview respondents said the inclusive approach of these interventions translated into women having better access to: (1) inputs, that is, quality fingerlings and commercial feed; (2) training in aquaculture production and climate change adaptation strategies; and (3) weather information and information about potential fish offtakers (buyers) and linkages to output markets.

The participation of women in the IBEMs project was lower than expected because many women entrepreneurs could not meet the financial requirements to join the program. While both women and men faced challenges of insufficient capital to engage in the fish farming value chain, these challenges were more pronounced for women. Women also feared societal shame if they would default on a loan, which is partly linked to their perception that they do not have the same drive and capacity as men to repay a sizable loan. This hindered women from considering credit as a source of capital. When women did get loans, they often opted for small loans from informal credit providers or village savings groups.

At the household level—although both women and men often lack the financial resources to purchase inputs or engage in climate change adaptation strategies (e.g., livelihood diversification)—women are often more disadvantaged than men in accessing aquaculture-related resources. Yet the FGD discussions confirmed that women had more opportunity to participate in training sessions related to aquaculture and climate change adaptation strategies as a result of the WorldFish interventions.

Another notable qualitative finding from the study was about the establishment of women fish farmer cooperatives, which were facilitated and supported by the WorldFish and IBEMs interventions. These cooperatives have brought many women into aquaculture and facilitated women's access to and control of resources in aquaculture. For example, during the FGDs with the Kasakalabwe cooperative it emerged that most women in these cooperatives felt they could pool their meager resources and acquire shared access to and control over the resources owned by their cooperatives.

While in this context women generally have limited access to land, which is critical to pond ownership, FGD respondents indicated that men spouses and traditional leaders did tend to be willing to grant women and women's groups access to land to enable their engagement in fish production. At times, they also provided labor to help women dig ponds, which women and men both said is difficult for women due to physical limitations. While the custom constraining women from owning land or only inheriting it on behalf of their children is unlikely to have changed, still, in the context of fish farming, specifically through cooperatives, women are able to own a fishpond through the support of their spouses or traditional leaders.

5.3.4 Women's roles and decision-making power in aquaculture

The FGDs revealed that women and men have different responsibilities in fish farming. Men take on the more capital-intensive, physically demanding and periodic tasks and are responsible for determining sales prices. In contrast, women typically engage in daily, time-consuming chores, often related to nurturing the fish and fishpond (Table 8). These socially constructed gendered roles in aquaculture often also put women at a disadvantage in controlling and having access to aquaculture resources. As is evident from the quote below, these gendered roles have implications for women's decision-making power as well, and, consequently, for the way IBEMs participants can support women fish farmers.

Because of the culture, the man usually keeps the money, so if you speak to the woman alone, it is a challenge for her to work without her husband. (SME owner, Busekelelo)

Table 8. Women’s and men’s ascribed responsibilities in fish farming

Fish farming activities	Women responsible		Men responsible	
	Women FGD	Men FGD	Women FGD	Men FGD
Fish farm expansion			x	
Fencing pond				x
Stocking/buying fingerlings				x
Water management			x	x
Feeding	x	x		
Pond maintenance	x	x		
Fish health monitoring	x	x		
Harvesting		x	x	
Sales price			x	x

The FGDs with fish farmers revealed that women farmers in joint or family enterprises were less likely to have decision-making power across the value chain nodes (production, harvesting and marketing). FGD respondents linked women’s limited decision-making power, in part, to social norms that identify men as the head of their households. Therefore, despite women and men alluding to a collaborative decision-making approach in their households or enterprises, respondents agreed that men have more influence in decision-making on how or when joint or family fish farming enterprise activities should proceed. Women and men respondents agreed that marketing-related decisions, such as the selection of offtakers and sale prices, and decisions on how the income from fish sales is spent are largely influenced by men.

We all make decisions together. If I let my husband make that decision alone, I might not agree. (W4)

It’s the man who makes the final decision in my household. (W2)

Yes, there are some decisions that I can make. Knowing my husband is not active in fish farming, I can be on top and make the decisions alone. (W3) (FGD with women fish farmers, Kasumpa, Kasof)

The challenge of social norms limiting women’s decision-making power in fish farming is specific to joint or family enterprises. According to some FGD respondents, men’s influence in decision-making is such that women only make decisions when men are away from the farm or when women are the sole owners of a pond. In situations where women are the sole owners of the enterprise or operate as part of a women’s group, women tend to have (more) control over all fish farming resources and decision-making power over production, harvesting and marketing, including over decisions on how the income from the venture is used. Yet it is important to note that, even when women own their own pond, in many cases, they are not exempted from working in the family (fish farming) enterprise—meaning that, in some instances, these women (and their children) face a significant work burden.

6. Discussion

Results show a positive relationship between the gender-intentional and gender-responsive aquaculture interventions that intentionally challenge gendered constraints related to access to resources, agency and roles in aquaculture and: (1) women's access to information on aquaculture, (2) women's involvement in (sole or joint) aquaculture-related decision-making, (3) women's awareness, knowledge and adoption of aquaculture-related climate-smart practices, and (4) women's diet diversity and household food security. A weak but negative relationship was observed with women's control over income from fishpond culture. Qualitative findings illustrate the motivating effects of women role models, the importance of cooperatives for women to gain access to land for fishponds, and how gendered roles and responsibilities are tied with gendered control over aquaculture resources and decision-making power, to women's disadvantage.

Aquaculture, particularly fish farming, is an important source of income and food in the study areas of Northern and Luapula provinces in Zambia. These provinces have been identified as areas where high climate risk (Filipski & Belton 2018) and significant gender inequalities in agrifood systems converge (Lecoutere et al. 2023). Climate change events such as droughts and floods negatively affect fish farming. The aquaculture value chain in these provinces is characterized by gender-based inequality in participation, access to resources, decision-making power and benefits that disadvantage women.

Addressing such gender inequalities and ensuring that both women and men have adequate climate-adaptive capacities is not only important to support equal opportunities in building a livelihood through aquaculture but also to sustain and enhance food production and productivity in aquaculture-based food systems in the face of climate change.

The objective of this study is testing hypotheses that have been derived from the Gendered Food Systems Framework and frameworks linking gender and climate change in agrifood systems (Bryan et al. 2023; Kristjanson et al. 2017; Njuki et al. 2022) that addressing structural gendered constraints to access to and control over resources, including technology, information and knowledge relevant for aquaculture as well as agency and roles in aquaculture supports (1) gender equality in involvement and access to resources in aquaculture (research hypothesis *RH1*); (2) women's empowerment in aquaculture (*RH2*); (3) gender equality in aquaculture-related climate-adaptive capacities (*RH3*); and (4) food and nutrition outcomes (*RH4*). We test these hypotheses by examining the extent to which gender-intentional and gender-responsive aquaculture interventions, as implemented by WorldFish in Northern and Luapula provinces in Zambia, are associated with indicators for each of these four outcomes. Given that women are generally disadvantaged in this context, these indicators look at outcomes that will capture change in gender equality for women. We relied on primary qualitative data and quantitative data collected in treatment and control groups between October 2022 and May 2023. We tested the relationship between participating in the interventions and the outcomes of interest using PSM as a quasi-experimental method. We additionally compared population-level pro-WEAI indices between treatment and control groups.

Firstly, access to and control over resources, technology and information is critical for poverty alleviation, intrahousehold decision-making, empowerment and involvement in value chain systems (Galiè et al. 2015; Johnson et al. 2016; Kruijssen et al. 2018; Meinzen-Dick et al. 2019). Assets and resources include knowledge, skills, networks, technologies and extension services (Miranda et al. 2016; Ndanga et al. 2013; Van Eerdewijk et al. 2017; Murendo et al. 2020). In support of the first research hypothesis, the quantitative results show a relatively strong positive relationship between intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture and women accessing information

on aquaculture (*RH1*). There is no evidence of a relationship with women's involvement in aquaculture and their access to productive resources for aquaculture. A first plausible explanation for these results relates to the interventions not focusing on access to material resources and assets but rather on access to aquaculture services (extension services, access to input and output resources) and information on effective aquaculture practices and technology, including climate-resilient practices. Another plausible explanation is that changing women's access to immaterial assets such as knowledge and information faces less strong gender norms than access to productive resources such as land and financial capital (Van Eerdewijk et al. 2017). This reasoning is supported by the pro-WEAI analysis in this study which identified lack of ownership of land and other assets, as well as access to and decisions on credit, as key contributing factors to women's disempowerment.

The qualitative findings provide some support for this first hypothesis and add important nuance; for instance:

- Despite a tendency that men are more likely to be members of farm cooperatives than women (Kruijssen et al. 2018), the gender-responsive aquaculture interventions have succeeded in mobilizing women to form fish farming cooperatives (see also Anh et al. 2011). Importantly, women's access to land, necessary for establishing fishponds, has been facilitated through women's fish farming cooperatives, and, at times, actively supported by men and community leaders; yet deeply engrained gendered norms and customs around land ownership are unlikely to have changed.
- Women continue to face financial constraints to entering the aquaculture value chain—even to qualify for some of the aquaculture interventions—yet they are hesitant to take on loans to deal with this constraint. This potentially hinders efforts to include women in aquaculture interventions and promote women's access to financial capital.
- The gender-responsive interventions encouraged women role models in the aquaculture value chain through intentional inclusion, support and training of women fish farmers and fish farming entrepreneurs. Successful women fish farmers and fish farming input dealers who gained access to a pond were able to stock it and acquire feed have emerged as role models in their rural communities. The role model effects for women potentially contribute to bridging the gender gap identified by Ndanga et al. (2013) regarding the unequal distribution of benefits from aquaculture. Interestingly, role model effects from women fish farmers or aquaculture entrepreneurs work differently for women and men. Women role models motivate women to engage in fish farming by inspiring them and raising their aspirations for gaining financial and other (nutritional) benefits through fish farming. They motivate men through sparking competition.

Secondly, the quantitative findings regarding the second research hypothesis are mixed. We find that intentionally challenging gender constraints to accessing resources, agency and roles in aquaculture interventions is positively related with women's involvement in (sole or joint) aquaculture-related decision-making, but slightly negatively related with women's control over income from fishpond culture (*RH2*). The latter resonates with a study by Halim and Ahmed (2006) that observed that most women had no or limited control over the income from aquaculture activities, neither in the treatment nor the control areas, and that men usually control and decide on the use of income derived from aquaculture. We acknowledge that selection bias may be present due to the lack of an identification strategy, and we cannot test whether the differences observed are statistically significant. The comparison of the three domains of empowerment (3DE) and pro-WEAI values between the treatment and control groups similarly suggest support for the hypothesis of a positive relationship between participating in the gender-responsive aquaculture interventions and women's empowerment in aquaculture (*RH2*). A plausible explanation for the mixed results pertaining to women's empowerment in aquaculture is that women's involvement in (sole or joint) aquaculture-related decision-making related to production, processing and/or marketing faces less strong gender norms and roles than control over income and is influenced more easily through gender-responsive interventions.

Mixed results on women's empowerment in aquaculture come up in other studies as well. Choudhury et al. (2017) found that increased roles of women in aquaculture do not necessarily lead to their empowerment. Kantor et al. (2015) argued that empowering effects of interventions that introduce knowledge or innovations can be limited if the social systems—including attitudes, norms, practices and institutions—remain unchanged. Synthesis studies demonstrated that mixed or null results are not uncommon when assessing the empowerment effects of agricultural development interventions using pro-WEAI based indicators (Quisumbing et al. 2023; 2024). Changes in empowerment are more likely when interventions are intentional about empowerment and sufficiently invest in it.

To some extent, the qualitative findings also support the second research hypothesis about a positive relationship between addressing gendered constraints to access to resources, agency and roles and women's empowerment in aquaculture (*RH2*) but mainly provide nuanced insights about this relationship:

- Roles and responsibilities in fish farming are gendered, and these gendered roles have implications for accessing and controlling aquaculture resources as well as for decision-making power over fish farming activities and income, to women's disadvantage.
- Gaining decision-making power and empowerment in aquaculture is harder for women in joint or family fish farming enterprises than for women who conduct such enterprises by themselves due to gender norms. This suggests that gender-responsive aquaculture interventions are less effective for women involved in joint or family fish farming enterprises compared to women with their own fish farming enterprise.
- Women with their own fish farming enterprises, however, are likely to face double work burdens as roles and norms expect them to contribute to the family enterprise as well. Since the pro-WEAI analysis in this study identified work balance as a key contributing factor to women's disempowerment, it seems important to mitigate such risks in interventions that promote women's involvement and agency in the aquaculture value chain.

Thirdly, qualitative findings attest to the challenges of climate change for fish farmers and aquaculture entrepreneurs in our study area. Droughts contribute to fish mortality when ponds dry up, and floods to fish losses when fish are washed away. Coping with climate change impacts is also costly for fish farmers and bad for business for aquaculture input dealers. The quantitative results provide support for the third research hypothesis that intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture in these climate-affected aquaculture-dependent food systems is positively associated with women's awareness, knowledge and adoption of aquaculture-related climate-smart practices. This can be assumed to strengthen their climate-adaptive capacities (*RH3*). Women's awareness was relatively high in the control group, which may explain why the interventions did not make a large difference. The largest differences pertain to knowledge and adoption. This suggests that the gender-responsive aquaculture interventions with extension services, demonstrations and series of training can be an effective way to enhance gender equality in "knowing" as well as "progressing into the adoption phase" of climate-smart aquaculture practices (noting that we do not yet have data to check changes in production levels)⁵ (Evenson 1997; Vecchio et al. 2023) and so contribute to gender equality in climate-adaptive capacities.

Fourthly, in support of the fourth research hypothesis, we found a positive relationship between intentionally challenging gendered constraints related to access to resources, agency and roles in aquaculture and women's individual diet diversity score, as well as a positive relationship with household food security (*RH4*). Aquaculture and fishpond farming have an impact pathway to better nutrition (Gonzalez Parrao et al. 2021), and the impact pathway of better and more gender-equal food and nutrition outcomes through reduced gendered constraints in the Gendered Food System Framework is supported by evidence

⁵ Following the Awareness Knowledge Adoption Product (AKAP) model by Evenson (1997).

showing, for instance, a positive relationship between women's access to financial resources, agency and mobility and nutrition outcomes (Njuki et al. 2022). Connecting this finding to earlier findings of increased gender equality in awareness, knowledge and adoption of aquaculture-related climate-adaptive practices, these results are in line with Béné and Devereux (2023) who state that people can deal with disturbances in food systems if they invest in resilience capacities, and that investments in adaptive and resilience capacities at the household level can enhance benefits from food systems.

Study limitations

The study faced some limitations. Northern and Luapula provinces in Zambia have areas that are remote and have poor road infrastructure. Since the fish farming households and enterprises were not connected with WorldFish in the control districts, their lack of organization and remoteness of the area hindered data collection; therefore, sample sizes in the control group were smaller than planned. Furthermore, while it would have been interesting to examine the differences between household and entrepreneurial fish farmers, the subsample of the latter in both the treatment and control groups was too small to run an analysis separate from fish farming households. The study had to rely on an ex-post quasi-experimental method of PSM to examine the relationship between the interventions and the outcomes. While statistical balance improved between treatment and control groups with the PSM procedure, selection bias cannot be ruled out and, while limited, there is some risk that the treatment and control groups could have been exposed to different events or trends. Spillovers are unlikely but cannot be fully ruled out. The comparison of population-level pro-WEAI related indices between the treatment and control groups could not be supported by statistical tests nor an identification method; therefore, we cannot infer firm conclusions about associations between the interventions and the empowerment indices. We found mixed quantitative results regarding changes in women's involvement in decision-making and control over income from aquaculture and nuanced qualitative results. It is not uncommon that quantitative and qualitative measures of women's empowerment are not in perfect harmony. Multiple reasons have been identified for seeming discrepancies, including a difference in quantitative and qualitative tools in measuring empowerment as a process and in capturing local understandings of empowerment in all their nuances, and the influence of gender norms on responses (Galiè et al. 2019; Njiru et al. 2024). We acknowledge some of these issues may have been occurring, but we could not explore this further within the scope of this study. Nevertheless, the fact that both the quantitative and qualitative findings attest that gaining control over income from aquaculture is difficult to achieve for women and that the qualitative results do not oppose the quantitative results but add nuance that decision-making power about aquaculture is easier to attain for women who manage their own fishpond indicates that the quantitative empowerment measures are meaningful.

7. Conclusion and next steps

Based on the study findings, we recommend that reducing gender inequality in participation; agency; roles; access to and control over resources, technology, information and knowledge in the aquaculture value chain in climate change-affected settings be pursued through gender-intentional and gender-responsive interventions that consider the complex and multilevel social, cultural, economic and political contexts influencing women's role, participation and capabilities in aquaculture. To achieve the desired impacts of enhancing (1) the gender equality of participation, access to and control over resources and assets, (2) women's empowerment in aquaculture, (3) climate-adaptive capacities, and (4) dietary benefits from food systems, interventions need to have a comprehensive strategy with gender-intentionality and gender-responsiveness throughout. Such a strategy includes (1) intentionally targeting women, (2) attention to gender-based constraints to women's participation in meetings and aquaculture-related training sessions, (3) providing access to relevant information on aquaculture and climate-resilient practices, (4) promoting women's empowerment in the aquaculture value chain through cooperatives, and (5) awareness raising among women and men, through training and women role models.

The study again highlighted women's key challenges within the aquaculture value chain, such as accessing finance, land, pond construction and other assets and productive resources for aquaculture; as well as having limited decision-making power over income derived from aquaculture. The interventions fell short of significantly addressing these challenges, all of which are subject to strong gender norms (Gonzalez Parrao et al. 2021; Kruijssen et al. 2016; USAID 2013). Change in these domains possibly requires interventions that are more than gender-intentional and gender-responsive but are rather gender-transformative by working more directly on changing the underlying norms.

Other recommendations to policymakers and practitioners on dealing with women's constrained resource access based on this study include:

1. Adapt eligibility criteria for aquaculture interventions that seem to exclude women on the basis of insufficient capital or assets to make interventions inclusive.
2. Focus gender-responsive interventions in the aquaculture value chain on expanding the linkages with multiple actors and stakeholders to partner in delivering enhanced gender-equal access to resources for aquaculture, and intentionally facilitate women's access to financial services and credit. These stakeholders include not only financial institutions, public and private sector extension providers and input service providers; they also include men and local leaders in the communities who can be important allies in reducing informal barriers to women's access to resources.
3. Continue to build on collective action and women's cooperatives to challenge the constraints regarding financial capital, land, assets and market access that women may not be able to confront as individuals.

We also derive the following recommendations related to enhancing women's agency and decision-making power from this study:

1. While challenging the gender norms that are at the basis of differences in gains in decision-making power for women who have their own aquaculture enterprise and women in joint and family enterprises could be pursued, for now, interventions could consider an adapted approach for these women.
2. To achieve gains in women's agency and decision-making power, interventions must adopt and invest in deliberate strategies that strengthen women's agency and decision-making power related to production, marketing and the use of income derived from engaging in aquaculture. Adopting gender-transformative approaches that also challenge the underlying normative constraints would likely be an even more effective approach as was shown in Cole et al. (2020) for the case of fish value chains in Zambia.
3. Extending the deliberate nurturing and support of women role models in the aquaculture value chain—where women who own an aquaculture enterprise can potentially be important sources of inspiration—can be an effective way to encourage women to participate and build their agency.
4. All the while, there is a need to monitor any possible negative consequences of enhancing women's involvement and agency in aquaculture, such as increased work burdens.

References

- Acosta, M., M. van Wessel, S. Van Bommel, et al. 2020. "What does it mean to make a 'joint' decision? Unpacking intra-household decision making in agriculture: Implications for policy and practice." *The Journal of Development Studies* 56 (6): 1210–1229. <https://doi.org/10.1080/00220388.2019.1650169>.
- Alkire, S., R. Meinzen-Dick, A. Peterman, A. Quisumbing, G. Seymour, and A. Vaz. 2013. "The Women's Empowerment in Agriculture Index." *World Development* 52: 71–91. <https://doi.org/10.1016/j.worlddev.2013.06.007>.
- Anderson, M. L. 2008. "Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and early training projects." *Journal of the American Statistical Association* 103 (484): 1481–1495. <https://doi.org/10.1198/016214508000000841>.
- Anh, P. T., S. R. Bush, A. P. J. Mol, et al. 2011. "The multi-level environmental governance of Vietnamese aquaculture: Global certification, national standards, local cooperatives." *Journal of Environmental Policy & Planning* 13 (4): 373–397. <https://doi.org/10.1080/1523908X.2011.633701>.
- Awiti, A. O. 2022. "Climate change and gender in Africa: A review of impact and gender-responsive solutions." *Frontiers in Climate* 4 (June). <https://doi.org/10.3389/fclim.2022.895950>.
- Béné, C., and S. Merten. 2008. "Women and fish-for-sex: Transactional sex, HIV/AIDS and gender in African fisheries." *World Development* 36 (5): 875–899. <https://doi.org/10.1016/j.worlddev.2007.05.010>.
- Béné, C., and S. Devereux, eds. 2023. *Resilience and Food Security in a Food Systems Context*. Springer Nature Link. <https://link.springer.com/book/10.1007/978-3-031-23535-1>.
- Braimoh, A., A. Mwanakasale, A. Chapoto, et al. 2018. "Increasing Agricultural Resilience through Better Risk Management in Zambia." Washington D.C.: World Bank Group. <http://documents.worldbank.org/curated/pt/330211524725320524/Increasing-agricultural-resilience-through-better-risk-management-in-Zambia>.
- Bryan, E., M. Alvi, S. Huyer, and C. Ringler. 2023. "Addressing gender inequalities and strengthening women's agency to create more climate-resilient and sustainable food systems." *Global Food Security* 40 (April): 100731. <https://doi.org/10.1016/j.gfs.2023.100731>.
- Central Statistical Office. 2019. "The 2017/2018 Livestock and Aquaculture Census: Summary Report." Lusaka, Zambia: Ministry of Fisheries and Livestock.
- Choudhury, A., C. McDougall, S. Rajaratnam, et al. 2017. "Women's Empowerment in Aquaculture: Two Case Studies from Bangladesh (Issue 1)." WorldFish and FAO. <https://hdl.handle.net/20.500.12348/270>.
- Cochrane, K. L., and S. M. Garcia. 2009. "A Fishery Manager's Guidebook." FAO/Wiley. <https://onlinelibrary.wiley.com/doi/book/10.1002/9781444316315>.
- Cole, S. M., A. M. Kaminski, C. McDougall, et al. 2020. "Gender accommodative versus transformative approaches: A comparative assessment within a post-harvest fish loss reduction intervention." *Gender, Technology and Development* 24 (1): 48–65. <https://doi.org/10.1080/09718524.2020.1729480>.
- Evenson, R. 1997. "The economic contributions of agricultural extension to agricultural and rural development." In *Improving Agricultural Extension. A Reference Manual*. Edited by B. E. Swanson, R. P. Bentz, and A. J. Sofranko. Rome: FAO. <https://www.fao.org/4/w5830e/w5830e06.htm>.
- FAO. 2018. "Food Insecurity Experience Scale (FIES)." Rome. <https://www.fao.org/in-action/voices-of-the-hungry/fies/en/>
- FAO. 2011. "Guidelines for Measuring Household and Individual Dietary Diversity." Rome. https://www.fao.org/fileadmin/user_upload/wa_workshop/docs/FAO-guidelines-dietary-diversity2011.pdf.
- Filipski, M., and B. Belton. 2018. "Give a Man a Fishpond: Modeling the Impacts of Aquaculture in the Rural Economy." *World Development* 110: 205–223. <https://doi.org/10.1016/j.worlddev.2018.05.023>.

- Galiè, A., A. Mulema, M. A. Mora Benard, et al. 2015. "Exploring gender perceptions of resource ownership and their implications for food security among rural livestock owners in Tanzania, Ethiopia, and Nicaragua." *Agriculture and Food Security* 4 (1): 1–14. <https://doi.org/10.1186/s40066-015-0021-9>.
- Galiè, A., N. Teufel, L. Korir, et al. 2019. "The Women's Empowerment in Livestock Index." *Social Indicators Research* 142: 799–825. <https://doi.org/10.1007/s11205-018-1934-z>.
- Gertler, P., S. Martinez, P. Premand, L. B. Rawlings, and C. M. Vermeersch. 2016. "Impact Evaluation in Practice (2nd ed.)." The World Bank.
- Gonzalez Parrao, C., S. Shisler, M. Moratti, et al. 2021. "Aquaculture for improving productivity, income, nutrition and women's empowerment in low- and middle-income countries: A systematic review and meta-analysis." *Campbell Systematic Reviews* 17 (4). <https://doi.org/10.1002/cl2.1195>.
- Halim, S., and M. K. Ahmed. 2006. "Women in fisheries in Bangladesh: Level of involvement and scope for enhancement." In *Global Symposium on Gender and Fisheries*, Penang, Malaysia, December 1–2, 2004. https://www.academia.edu/10254686/Global_Symposium_on_Gender_and_Fisheries_Seventh_Asian_Fisheries_Forum_1_2_December_2004_Penang_Malaysia.
- IFAD. 2016. "Enhanced-Smallholder Agribusiness Promotion Programme (E-SAPP) Final Programme Design Report." <https://webapps.ifad.org/members/eb/119/docs/EB-2016-119-R-22-Project-Design-Report.pdf>. IFAD.
- Johnson, N. L., C. Kovarik, R. Meinzen-Dick, et al. 2016. "Gender, assets, and agricultural development: Lessons from eight projects." *World Development* 83 (July 2016): 295–311. <https://doi.org/10.1016/j.worlddev.2016.01.009>.
- Kabeer, N. 1999. "Resources, Agency, Achievements: Reflections on the Measurement of Women's Empowerment." *Development and Change* 30 (3): 435–464. <https://doi.org/https://doi.org/10.1111/1467-7660.00125>.
- Kantor, P., M. Morgan, and A. Choudhury. 2015. "Amplifying outcomes by addressing inequality: The role of gender-transformative approaches in agricultural research for development." *Gender, Technology and Development* 19 (3): 292–319. <https://doi.org/10.1177/0971852415596863>.
- Kassam, L., and A. Dorward. 2017. "A comparative assessment of the poverty impacts of pond and cage aquaculture in Ghana." *Aquaculture* 470: 110–122. <https://doi.org/10.1016/j.aquaculture.2016.12.017>.
- Kawarazuka, N. 2010. *The Contribution of Fish Intake, Aquaculture, and Small-scale Fisheries to Improving Nutrition: A Literature Review*. The WorldFish Center Working Paper No.2106. The WorldFish Center, Penang, Malaysia. <https://digitalarchive.worldfishcenter.org/server/api/core/bitstreams/82f71b4b-13e3-4a74-9fbe-f2c07d9324bc/content>.
- Kristjanson, P., E. Bryan, Q. Bernier, J. Twyman, R. Meinzen-Dick, C. Kieran, C. Ringler, C. Jost, and C. Doss. 2017. "Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going?" *International Journal of Agricultural Sustainability* 15 (5): 482–500. <https://doi.org/10.1080/14735903.2017.1336411>.
- Kruijssen, F., C. L. McDougall, and I. J. M. van Asseldonk. 2018. "Gender and aquaculture value chains: A review of key issues and implications for research." *Aquaculture* 493: 328–337. <https://doi.org/10.1016/j.aquaculture.2017.12.038>.
- Kruijssen, F., S. Rajaratnam, A. Choudhury, et al. 2016. "Gender in the farmed fish value chain of Bangladesh: A review of the evidence and development approaches." WorldFish. Program Brief: 2016-38. <https://hdl.handle.net/20.500.12348/258>.
- Lecoutere, E., K. Kosec, A. Quisumbing, M. Elias, E. Bryan, and R. Puskur. 2023. "Equality and Empowerment by Gender and Intersecting Social Differentiation in Agri-food Systems: Setting the Stage." CGIAR GENDER Impact Platform Working Paper #008. Nairobi, Kenya: CGIAR GENDER Impact Platform. <https://hdl.handle.net/10568/129704>.
- Mapedza, E., S. Huyer, N. Chanana, et al. 2023. "Framework for incorporating gender equality and social inclusion (GESI) elements in climate information services (CIS)." *Sustainability* 15: 190. <https://doi.org/10.3390/su15010190>.
- Malapit, H., A. Quisumbing, R. Meinzen-Dick, et al. 2019. "Development of the project-level women's empowerment in agriculture index (pro-WEAI)." *World Development* 122: 675–692.

- Maulu, S., O. J. Hasimuna, M. Chibesa, et al. 2024. "Perceived effects of climate change on aquaculture production in Zambia: status, vulnerability factors, and adaptation strategies." *Frontiers in Sustainable Food Systems* 8. <https://doi.org/10.3389/fsufs.2024.1348984>.
- McKenzie, D. 2020. "An Overview of Multiple Hypothesis Testing Commands in Stata." *World Bank Blogs*. June 1, 2020. <https://blogs.worldbank.org/en/impactevaluations/overview-multiple-hypothesis-testing-commands-stata>.
- Meinzen-Dick, R., A. Quisumbing, C. Doss, et al. 2019. "Women's land rights as a pathway to poverty reduction: Framework and review of available evidence." *Agricultural Systems* 172 (November 2017): 72–82. <https://doi.org/10.1016/j.agsy.2017.10.009>.
- Ministry of Gender for the Republic of Zambia. 2016. Climate change gender action plan of the Republic of Zambia. Republic of Zambia. <https://portals.iucn.org/union/sites/union/files/doc/ccgap-zambia-final-web.pdf>.
- Miranda, M., T. Geraldine, R. Surendran, et al. 2016. "Socio-cultural dynamics shaping the potential of aquaculture to deliver development outcomes." *Reviews in Aquaculture* 9 (4): 317–325. <https://onlinelibrary.wiley.com/doi/10.1111/raq.12137>.
- Murendo, C., G. Kairezi, and K. Mazvimavi. 2020. "Resilience capacities and household nutrition in the presence of shocks. Evidence from Malawi." *World Development Perspectives* 20: 100241. <https://doi.org/https://doi.org/10.1016/j.wdp.2020.100241>.
- National Fisheries and Aquaculture Policy (2014). Zambia Ministry of Fisheries and Livestock.
- Ndanga, L. Z. B., K. K. Quagraine, and J. H. Dennis. 2013. "Economically feasible options for increased women participation in Kenyan aquaculture value chain." *Aquaculture* 414–415: 183–190. <https://doi.org/10.1016/j.aquaculture.2013.08.012>.
- Ng'onga, M., F. Kanungwe Kalaba, J. Mwitwa, et al. 2019. "The interactive effects of rainfall, temperature and water level on fish yield in Lake Bangweulu fishery, Zambia." *Journal of Thermal Biology* 84: 45–52. <https://doi.org/10.1016/j.jtherbio.2019.06.001>.
- Njuki, J., S. Eissler, H. Malapit, R. Meinzen-Dick, E. Bryan, and A. Quisumbing. 2022. "A review of evidence on gender equality, women's empowerment, and food systems." *Global Food Security* 33: 100622. <https://doi.org/https://doi.org/10.1016/j.gfs.2022.100622>.
- Njiru, N., A. Galiè, I. Omondi, et al. 2024. "Gender transformative innovation: Women's inclusion in livestock vaccine systems in northern Ghana." *Agricultural Systems* 219 (August): 104023. <https://doi.org/10.1016/j.agsy.2024.104023>.
- Nyangu, C. 2016. "Combating climate change. Fisheries and aquaculture in Zambia." Munich: GRIN Verlag.
- Oyebola, O. O., J. Efitre, L. Musinguzi, et al. 2021. "Potential adaptation strategies for climate change impact among flood-prone fish farmers in climate hotspot Uganda." *Environment, Development and Sustainability* 3 (9): 12761–12790. <https://doi.org/10.1007/s10668-020-01183-1>.
- Quisumbing, A., S. Cole, M. Elias, et al. 2023. "Measuring women's empowerment in agriculture: Innovations and evidence." *Global Food Security* 38 (February): 100707. <https://doi.org/10.1016/j.gfs.2023.100707>.
- Quisumbing, A., R. Meinzen-Dick, H. J. Malapit, et al. 2024. "Enhancing agency and empowerment in agricultural development projects: A synthesis of mixed methods impact evaluations from the Gender, Agriculture, and Assets Project, Phase 2 (GAAP2)." *Journal of Rural Studies* 108: 103295. <https://doi.org/10.1016/J.JRURSTUD.2024.103295>.
- Republic of Zambia. 2023. "National Fisheries and Aquaculture Policy." Ministry of Fisheries and Livestock. Republic of Zambia. <https://faolex.fao.org/docs/pdf/zam224319.pdf>.
- Rösler, U., D. Hollmann, J. Naguib, A. Oppermann, and C. Rosendahl. 2013. "Inclusive business models: Options for support through PSD programmes." Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Germany. https://www.enterprise-development.org/wp-content/uploads/131014_giz_ib-models_rz_01_web.pdf.
- Seymour, G., N. Ferguson, C. van Biljon, et al. 2023. "User Guide on the Project-level Women's Empowerment in Agriculture Index (Pro-WEAI)." Washington D.C.: WEAI Resource Center. International Food Policy Research Institute. <https://weai.ifpri.info/files/2023/07/Pro-WEAI-Guide.pdf>.

- Tirado, M. C., D. Hunnes, M. Cohen, et al. 2015. "Climate change and nutrition in Africa." *Journal of Hunger and Environmental Nutrition* 10 (1): 22–46. <https://doi.org/10.1080/19320248.2014.908447>.
- USAID. 2013. "Greater Harvest and Economic Returns from Shrimp (GHERS) Final Program Performance Report." WorldFish. <https://hdl.handle.net/20.500.12348/1198>.
- Van Eerdewijk, A., F. Wong, C. Vaast, et al. 2017. "White Paper: A Conceptual Model of Women and Girls' Empowerment." Amsterdam: Royal Tropical Institute (KIT).
- Vogel A, C. Barbiellini Amidei, N. N. Danso, et al. 2023. "Gender Norms and Climate-smart information in Northern Zambia." Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) report. WorldFish and AICCRA. <https://hdl.handle.net/10568/131319>
- Vecchio, Y., M. Masi, and F. Adinolfi. 2023. "From the AKAP to AKAIE model to assess the uptake of technological innovations in the aquaculture sector." *Reviews in Aquaculture* 15 (2): 772–784. <https://doi.org/10.1111/raq.12756>.
- Weeratunge, N., and K. Snyder. 2009. "Gleaner, fisher, trader, processor: Understanding gendered employment in the fisheries and aquaculture sector." In *FAO-IFAD-ILO Workshop on Gaps, trends and current research in gender dimensions of agricultural and rural employment: Differentiated pathways out of poverty*, Rome, Italy, March 31 – April 2, 2009.

Appendixes

Appendix 1. Descriptive statistics of outcome indicators

Outcome indicator Variable	Treatment			Control		
	Obs	Mean	Std. dev	Obs	Mean	Std. dev
Y1 = Women's involvement in aquaculture	322	0.786	0.411	178	0.753	0.433
Y2 = Women's involvement in control over the productive resources for aquaculture	299	0.943	0.232	169	0.929	0.258
Y3 = Women's involvement in ownership of land for fishpond construction	279	0.753	0.432	159	0.761	0.428
Y4 = Women's access to information on aquaculture	322	0.748	0.435	178	0.393	0.490
Y5 = Women's involvement in aquaculture-related decision-making	322	0.780	0.415	178	0.624	0.486
Y6 = Women's control over income from fishpond culture	320	0.978	0.147	177	0.938	0.242
Y7 = Women's awareness of climate-smart aquaculture practices	322	0.966	0.182	178	0.916	0.279
Y8 = Women's knowledge of climate-smart aquaculture practices	322	0.783	0.413	178	0.371	0.484
Y9 = Women's adoption of climate-smart aquaculture practices	322	0.876	0.330	178	0.747	0.436
Y10 = Women's Dietary Diversity Score (WDDS)	322	4.093	1.470	178	3.607	1.299
Y11 = Food Insecurity Experience Scale (FIES) based on women's responses	322	4.624	3.299	178	5.652	3.074

Appendix 2. Descriptive statistics of matching variables

Variable	Treatment $n = 322$		Control $n = 178$	
	Mean	Std. dev	Mean	Std. dev
Distance to market	11.593	7.458	10.348	7.414
Income (ZK)	1,604.037	1,796.297	1,250.000	1,394.349
Household size	7.488	2.575	8.326	2.692
Proportion of women in household	0.601	0.214	0.604	0.200
Household owns land	0.876	0.330	0.882	0.323
Own large livestock	0.078	0.268	0.039	0.195
Own small livestock	0.457	0.499	0.433	0.497
Own poultry and other small animal	0.823	0.382	0.742	0.439
Own fishpond or fishing equipment	0.863	0.344	0.736	0.442
Own non-mechanized farm equipment	0.416	0.494	0.421	0.495
Own non-farm business equipment	0.453	0.499	0.438	0.498
Own house or building	0.854	0.354	0.860	0.348
Own large consumer durables e.g., TV	0.391	0.489	0.242	0.429
Own small consumer durables e.g., radio	0.708	0.455	0.539	0.500
Own cell phone(s)	0.854	0.354	0.848	0.360
Own other land not used for agricultural purposes	0.556	0.498	0.584	0.494
Own means of transportation	0.786	0.411	0.758	0.429
Own pond-construction equipment	0.904	0.295	0.854	0.354
Own irrigation equipment	0.081	0.273	0.067	0.251
Own fish-harvesting equipment	0.255	0.436	0.152	0.360
Own fish-processing equipment	0.391	0.489	0.287	0.453

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 3. Balance Tables Y1: Likelihood of women's (sole or joint) involvement in control over the productive resources for aquaculture

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 4. Balance tables Y2: Likelihood of women's (sole or joint) involvement in control over the productive resources for aquaculture

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.216	-0.027	1.004	1.097
Income	0.175	-0.137	1.508	0.807
Household size	-0.299	0.011	0.897	0.973
Proportion of women in household	-0.048	-0.064	1.090	1.030
Household owns land	0.058	0.044	0.811	0.853
Own large livestock	0.151	0.026	1.784	1.093
Own small livestock	0.042	-0.133	1.005	0.979
Own poultry and other small animal	0.150	0.075	0.795	0.892
Own fishpond or fishing equipment	0.271	0.011	0.642	0.981
Own non-mechanized farm equipment	0.016	0.000	1.002	1.000
Own non-farm business equipment	0.061	-0.039	1.009	0.993
Own house or building	0.009	-0.003	0.977	1.007
Own large consumer durables e.g., TV	0.302	-0.045	1.268	0.969
Own small consumer durables e.g., radio	0.337	-0.038	0.835	1.025
Own cell phone(s)	-0.049	-0.009	1.106	1.018
Own other land not used for agricultural purposes	-0.049	0.002	1.017	0.999
Own means of transportation	0.028	-0.031	0.959	1.041
Own pond-construction equipment	0.145	0.000	0.697	1.000
Own irrigation equipment	0.059	-0.104	1.201	0.741
Own fish-harvesting equipment	0.265	-0.008	1.456	0.991
Own fish-processing equipment	0.189	0.026	1.127	1.017
Own fish-storage equipment	0.101	-0.039	1.089	0.968

Total raw $n = 468$, matched = 936; treatment observations raw = 299, matched = 468

Appendix 5. Balance tables Y3: Likelihood of women's (sole or joint) involvement in ownership of land for fishpond construction

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.256	0.052	0.996	1.038
Income	0.150	-0.076	1.429	1.017
Household size	-0.319	0.113	0.893	1.077
Proportion of women in household	-0.053	-0.055	1.119	1.080
Household owns land	0.144	0.016	0.528	0.935
Own large livestock	0.158	0.148	1.792	1.665
Own small livestock	0.014	-0.104	0.999	0.997
Own poultry and other small animal	0.155	-0.022	0.784	1.036
Own fishpond or fishing equipment	0.271	-0.003	0.628	1.005
Own non-mechanized farm equipment	0.023	0.042	1.005	1.013
Own non-farm business equipment	0.075	-0.023	1.008	0.996
Own house or building	-0.018	-0.035	1.040	1.090
Own large consumer durables e.g., TV	0.308	0.014	1.265	1.009
Own small consumer durables e.g., radio	0.335	-0.040	0.825	1.029
Own cell phone(s)	-0.062	0.100	1.137	0.813
Own other land not used for agricultural purposes	-0.088	-0.047	1.042	1.023
Own means of transportation	0.032	-0.039	0.952	1.060
Own pond-construction equipment	0.135	0.049	0.710	0.891
Own irrigation equipment	0.051	-0.071	1.166	0.832
Own fish-harvesting equipment	0.291	0.011	1.504	1.012
Own fish-processing equipment	0.137	0.015	1.090	1.008
Own fish-storage equipment	0.071	-0.062	1.061	0.948

Total raw $n = 438$, matched = 876; treatment observations raw = 279, matched = 438

Appendix 6. Balance tables Y4: Likelihood of women's (sole or joint) involvement in access to information on aquaculture

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 7. Balance tables Y5: Likelihood of women's (sole or joint) involvement in aquaculture decision-making

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 8. Balance tables Y6: Likelihood of women controlling income from aquaculture activities

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.178	0.026	1.020	1.016
Income	0.216	-0.061	1.660	0.923
Household size	-0.332	0.047	0.918	1.031
Proportion of women in household	-0.003	-0.013	1.174	1.163
Household owns land	-0.037	0.047	1.089	0.892
Own large livestock	0.164	0.068	1.891	1.291
Own small livestock	0.043	-0.076	1.007	0.985
Own poultry and other small animal	0.198	0.035	0.759	0.953
Own fishpond or fishing equipment	0.310	0.028	0.615	0.957
Own non-mechanized farm equipment	-0.023	0.049	0.990	1.016
Own non-farm business equipment	0.030	0.069	1.004	1.016
Own house or building	-0.016	0.023	1.030	0.956
Own large consumer durables e.g., TV	0.327	0.020	1.295	1.013
Own small consumer durables e.g., radio	0.343	-0.002	0.834	1.001
Own cell phone(s)	0.016	0.074	0.967	0.874
Own other land not used for agricultural purposes	-0.063	-0.005	1.016	1.001
Own means of transportation	0.065	0.084	0.917	0.896
Own pond-construction equipment	0.164	0.020	0.676	0.955
Own irrigation equipment	0.051	-0.044	1.178	0.875
Own fish-harvesting equipment	0.244	-0.005	1.447	0.994
Own fish-processing equipment	0.224	0.056	1.161	1.038
Own fish-storage equipment	0.117	0.050	1.111	1.045

Total raw $n = 497$, matched = 1,000; treatment observations raw = 320, matched = 177

Appendix 9. Balance tables Y7: Women's awareness of climate-smart practices

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 10. Balance tables Y8: Women's knowledge of climate-smart practices

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 11. Balance tables Y9: Women's adoption of climate-smart practices

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 12. Balance tables Y10: Women's Dietary Diversity Score (WDDS) based on women's responses

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 13. Balance tables Y11: Food Insecurity Experience Scale (FIES) based on women's responses

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Distance to market	0.167	-0.002	1.012	1.038
Income	0.220	-0.019	1.660	1.023
Household size	-0.318	-0.027	0.915	1.007
Proportion of women in household	-0.017	0.039	1.149	1.234
Household owns land	-0.019	-0.036	1.043	1.087
Own large livestock	0.163	0.054	1.891	1.219
Own small livestock	0.048	-0.082	1.008	0.986
Own poultry and other small animal	0.198	-0.030	0.758	1.043
Own fishpond or fishing equipment	0.322	-0.004	0.606	1.007
Own non-mechanized farm equipment	-0.011	0.101	0.994	1.041
Own non-farm business equipment	0.031	0.023	1.004	1.004
Own house or building	-0.016	0.029	1.030	0.942
Own large consumer durables e.g., TV	0.326	0.062	1.297	1.045
Own small consumer durables e.g., radio	0.353	-0.003	0.830	1.002
Own cell phone(s)	0.016	0.049	0.966	0.914
Own other land not used for agricultural purposes	-0.057	0.013	1.014	0.997
Own means of transportation	0.065	0.055	0.917	0.936
Own pond-construction equipment	0.153	-0.031	0.696	1.080
Own irrigation equipment	0.051	-0.007	1.178	0.979
Own fish-harvesting equipment	0.258	-0.007	1.471	0.991
Own fish-processing equipment	0.222	0.107	1.162	1.072
Own fish-storage equipment	0.116	0.036	1.111	1.031

Total raw $n = 500$, matched = 1,000; treatment observations raw = 322, matched = 178

Appendix 14. Descriptive statistics of respondents' socio-demographic characteristics

Both women and men adult co-heads of fish farmer households responded to the survey. There were 178 women and 178 men household respondents in the control group and 322 women and 322 men household respondents in the treatment group ([Table 9](#)). Most respondents in the control and treatment groups are married. Most women and men fish farmers in both control and treatment groups are between the ages of 36 and 64 years, suggesting that most respondents were in the active working age group. Most farmers in both groups have had between six and 10 years of schooling (55 percent of women and 68 percent of men in the control, and 62 percent of women and 64 percent of men in the treatment). Men scored higher than women in the number of years in school. Generally, the descriptive statistics on years of schooling indicate a basic level of education and a likelihood that most farmers can read and write, which is important for developing and delivering training and reading materials on aquaculture.

Table 9. Descriptive statistics of respondents' socio-demographic characteristics

Variable	Category	Control					Treatment				
		Women	Men	% Women	% Men	Total	Women	Men	% Women	% Men	Total
Age	≤ 35	69	47	39%	26%	116	124	97	39%	30%	221
	36–64	105	109	59%	61%	214	188	191	58%	59%	379
	≥ 65	4	22	2%	12%	26	10	34	3%	11%	44
	Total	178	178	100%	100%	356	322	322	100%	100%	644
Marital status	Cohabiting	1	0	1%	0%	1	0	1	0%	0%	1
	Divorced	2	1	1%	1%	3	2	1	1%	0%	3
	Married	160	165	90%	93%	325	291	293	90%	91%	584
	Separated	1	0	1%	0%	1	2	0	1%	0%	2
	Single	11	10	6%	6%	21	12	16	4%	5%	28
	Widowed	3	1	2%	1%	4	9	4	3%	1%	13
	Other	0	1	0%	1%	1	6	7	2%	2%	13
Total	178	178	100%	100%	356	322	322	100%	100%	644	
Years in school	0	9	2	5%	1%	11	9	2	3%	1%	11
	1–5	56	12	31%	7%	68	73	20	23%	6%	93
	6–10	98	121	55%	68%	219	199	206	62%	64%	405
	11–15	13	41	7%	23%	54	41	89	13%	28%	130
	> 15	2	2	1%	1%	4	0	5	0%	2%	5
	Total	178	178	100%	100%	356	322	322	100%	100%	644
Household members	< 3	2	3	1%	2%	5	10	12	3%	4%	22
	3–5	40	34	22%	19%	74	104	100	32%	31%	204
	5–7	52	60	29%	34%	112	96	104	30%	32%	200
	7–10	60	59	34%	33%	119	89	85	28%	26%	174
	> 10	24	22	13%	12%	46	23	21	7%	7%	44
	Total	178	178	100%	100%	356	322	322	100%	100%	644



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