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The Role of Smallholder Aquaculture in Enhancing Livelihoods and Food Security in Pemba, Zanzibar – Tanzania

The Role of Smallholder Aquaculture in Enhancing Livelihoods and Food Security in Pemba, Zanzibar – Tanzania

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Abstract
Smallholder aquaculture is increasingly recognised as a viable livelihood strategy for enhancing food security and income in rural coastal communities, particularly within low- and middle-income countries. This study investigates the socio-economic contribution of smallholder aquaculture in Pemba, Zanzibar, through a mixed-methods approach employing an explanatory sequential design. Quantitative data were collected from 352 households, comprising both aquaculture practitioners and non-participants. Comparative analyses reveal that households engaged in aquaculture reported significantly higher monthly incomes, greater dietary diversity, and improved food security scores. Fish cage systems yielded the highest income returns, while access to land, education level, and existing fishing income were found to be significant predictors of aquaculture adoption. Despite these benefits, several systemic challenges were identified, including inadequate access to capital, poor input quality, and limited technical support. These constraints continue to hinder broader uptake and long-term sustainability. The findings underscore the need for integrated policy frameworks that support microfinance access, enhance extension services, and strengthen input markets through public–private collaboration. Aligning smallholder aquaculture development with national food security and climate resilience strategies could accelerate its transformation from a supplementary activity into a central pillar of rural development. The study contributes to the growing body of evidence advocating for inclusive, locally adapted aquaculture systems within the context of the blue economy.

Introduction

Aquaculture has become the fastest-growing food production sector globally, contributing significantly to the fight against food insecurity, rural poverty, and undernutrition. As wild fish stocks decline due to overfishing, habitat degradation, and climate change, the global demand for fish protein is increasingly being met by aquaculture, which now accounts for over half of the fish consumed worldwide (FAO, 2022). Smallholder aquaculture, typically managed at household or community levels, plays a crucial role in this transformation, especially in low- and middle-income countries where food and livelihood security remain persistent concerns (Brugere et al., 2021).

In Africa, the aquaculture sector is still in its nascent stages but has shown substantial potential for socio-economic development. However, the continent contributes only a small fraction to global aquaculture production due to systemic challenges such as inadequate infrastructure, poor access to technology and finance, and limited policy support (March & Failler, 2022; Rege & Ochieng, 2022).

Despite these limitations, recent years have seen a growing emphasis on aquaculture as a strategic sector for achieving food and nutritional security, particularly in regions vulnerable to climate change and economic instability.

Within East Africa, small-scale aquaculture has gained recognition for its ability to diversify rural livelihoods and enhance dietary intake. Studies from countries like Uganda, Kenya, and Tanzania highlight the sector's role in supplementing household incomes, improving dietary diversity, and reducing dependency on overexploited capture fisheries (Mulokozi et al., 2020; Shalli et al., 2024). Yet, the extent of aquaculture's contribution varies widely depending on geographical, environmental, and socio-economic contexts.

Tanzania, in particular, has made notable strides in promoting aquaculture as part of its blue economy agenda. The government and development partners have increasingly invested in the sector, aiming to improve coastal livelihoods and enhance resilience to climate-induced stressors (Makame et al., 2023; Brodie et al., 2024). However, the growth of aquaculture in Tanzania remains uneven, with most activity concentrated on the mainland in areas like Mwanza and the Lake Zone (Mdoe et al., 2025). In contrast, Zanzibar, despite being surrounded by rich marine ecosystems, has yet to capitalise on the potential of smallholder aquaculture fully.

Zanzibar's coastal communities, especially on Pemba Island, continue to rely heavily on small-scale fishing and seaweed farming. However, these activities are increasingly vulnerable to overexploitation and environmental variability, necessitating livelihood diversification (Mwanyoka et al., 2025; Makame & Salum, 2021). Smallholder aquaculture is emerging as a promising alternative, offering opportunities to enhance household food security and income. Yet, empirical data on its actual impact in Zanzibar's context is scarce, and the sector remains under-researched compared to other coastal livelihood strategies (Ali et al., 2024; Newman et al., 2024).

The purpose of this paper is to examine the contribution of smallholder aquaculture to household income, food security, and overall livelihoods in Pemba, Zanzibar. By analysing survey data and comparing aquaculture and non-aquaculture households, this study aims to provide empirical evidence on the socio-economic benefits and challenges of smallholder aquaculture. The findings are intended to inform policy, investment, and development strategies aimed at fostering inclusive and sustainable aquaculture growth within Zanzibar and similar Small Island developing contexts.

Methodology

Study Design

This study employed an explanatory sequential design, a type of mixed-methods research where quantitative data collection and analysis are conducted first, followed by qualitative exploration to help explain or elaborate on the statistical findings (Creswell & Plano Clark, 2018). The approach was chosen to provide a robust understanding of the socio-economic contributions of smallholder aquaculture, allowing for not only statistical comparison but also contextual interpretation grounded in lived experience.

Study Area

This research was carried out on Pemba Island, one of the two main islands that make up the semi-autonomous region of Zanzibar, Tanzania. Pemba is known for its rich marine biodiversity and a population that relies heavily on traditional coastal activities such as artisanal fishing, seaweed farming, and small-scale farming. Despite this ecological potential, the island still lacks significant investment in aquaculture infrastructure and has received relatively little policy attention when compared to mainland Tanzania.

The study focused on several districts across the island, including Micheweni, Wete, Chake Chake, and Mkoani, all of which are marked in *Figure 1: Location of the Study Areas*. These areas were selected because they reflect the geographic and socio-economic diversity of coastal communities in Pemba, providing a solid foundation for comparative analysis between aquaculture and non-aquaculture households.

As shown in Figure 1, the districts are spread along both the eastern and western coasts of the island, allowing the study to capture variations in access to marine resources, infrastructure, and exposure to external interventions. This geographic layout also helped ensure that the findings would be broadly representative of coastal livelihoods across Pemba.

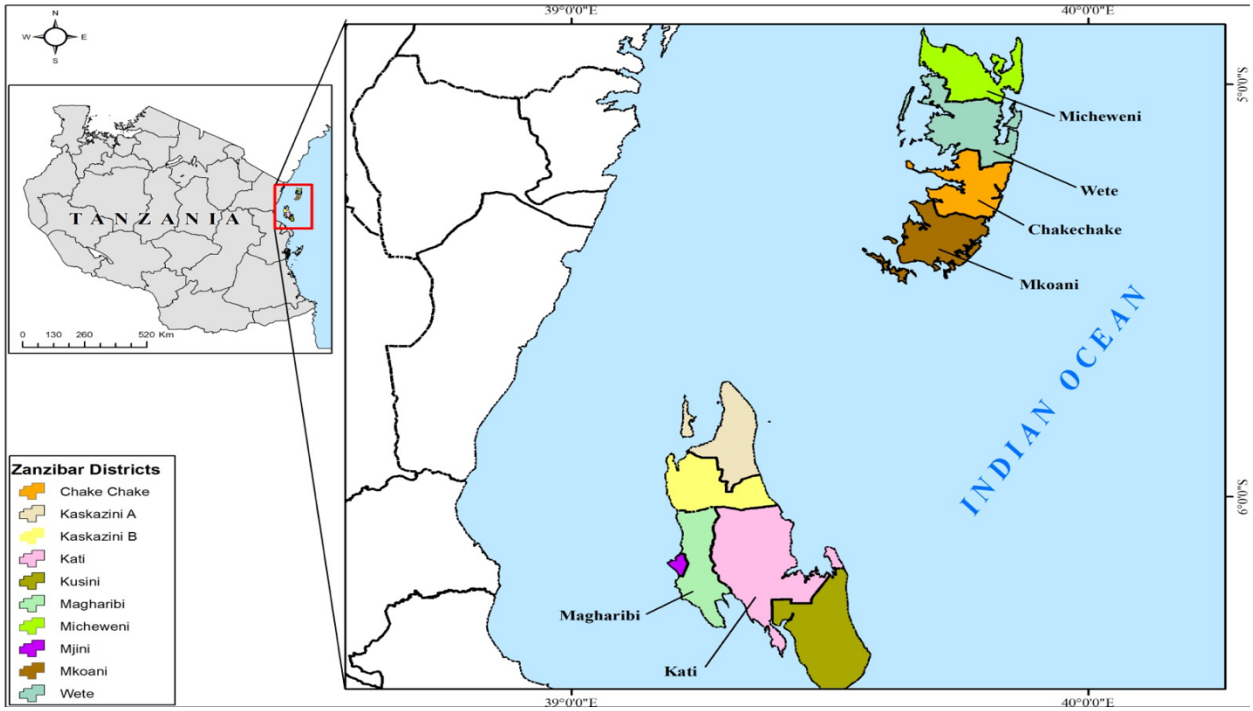

Figure 1: Location of the Study Areas

Source: UDSM, Department of Geography (2025)

Study Population

The study targeted coastal households in Pemba with a focus on those either engaged in smallholder aquaculture or reliant on traditional fishing livelihoods. These included both direct aquaculture practitioners and non-aquaculture households in the same communities, enabling comparative analysis. The population was broadly representative of rural coastal dwellers, many of whom rely on natural resources for subsistence and income.

Sample size and sampling technique

The sample for this study consisted of 352 households selected from coastal communities across Pemba Island. The determination of this sample size was guided by Yamane's (1967) formula for calculating sample sizes in large populations:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = sample size

N = estimated population size

e = margin of error (commonly set at 0.05 for a 95% confidence level)

Given the estimated rural household population in the study districts to be approximately 8,000, and using a 5% margin of error, the formula yields:

$$n = \frac{8000}{1 + 8000(0.05)^2} = \frac{8000}{1 + 20} = \frac{8000}{21} \approx 381$$

While the calculated ideal sample size was approximately 381, the study settled on a slightly lower yet statistically acceptable sample of 352 households due to logistical constraints and field accessibility. This still falls within an adequate margin of error and ensures strong statistical reliability for comparative analysis.

A purposive sampling technique was employed to select communities with known or emerging aquaculture activity. This approach ensured that both aquaculture practitioners and non-practising households were adequately represented. Among the sampled households, 32 were involved in smallholder aquaculture, while the remaining 320 households reflected other coastal livelihoods such as fishing, seaweed farming, and agriculture.

This sampling design enabled meaningful comparisons between the two groups, providing a well-rounded understanding of the socio-economic effects of aquaculture within the broader coastal context of Pemba Island.

Data Collection

Data collection was primarily quantitative and involved structured household surveys administered face-to-face. The questionnaire captured demographic data, economic indicators (e.g., income, land access), food and nutrition metrics (e.g., food security scores, dietary diversity), and livelihood activities. The tool was piloted before full deployment to ensure clarity and relevance, and was translated into Kiswahili to accommodate local respondents.

Secondary data, including contextual information and literature, were also reviewed to support the interpretation of findings and to situate the results within broader regional and global discourses on aquaculture and food security.

Data Analysis

Quantitative data were entered into SPSS (Version 25) for analysis. Descriptive statistics were used to profile household characteristics, while independent samples t-tests and ANOVA assessed differences in socio-economic outcomes between aquaculture and non-aquaculture households. Logistic regression was employed to identify significant predictors of aquaculture adoption, and Pearson correlation analysis was used to explore relationships between key variables such as aquaculture income, food security, and dietary diversity.

Chi-square tests were applied to examine reported challenges faced by aquaculture practitioners, and all inferential statistics were interpreted at standard significance levels ($p < 0.05$, $p < 0.01$, and $p < 0.001$).

Ethical Considerations

The study followed strict ethical guidelines from start to finish. All participants gave informed consent after the research team clearly explained the study's purpose, their voluntary role in it, and their right to walk away at any point. To protect privacy, personal details were never used; instead, participants were identified using coded numbers.

Before any fieldwork began, ethical approval and official research permits were secured from the Second Vice President's Office (Research Permit Section) in Zanzibar. This permission covered both North and South Pemba Regions. The permit specifically instructed the District Commissioners in Micheweni, Wete, Chake Chake, and Mkoani to support the research team with data collection efforts in their areas. Having that formal permission not only ensured everything was done in accordance with the guiding research regulations but also helped gain the trust and cooperation of the local communities.

Results

This section presents the quantitative findings from the survey of 352 households across Pemba Island, Zanzibar. The analysis compares households engaged in smallholder aquaculture with those relying on other coastal livelihoods, highlighting differences in income, food security, dietary diversity, and other socio-economic indicators.

Participation in Aquaculture Activities

Out of the 352 surveyed households, 32 (9.1%) reported active participation in aquaculture activities, while the remaining 320 households (90.9%) did not engage in aquaculture. Among the aquaculture households, the most common system was fishponds (56.3%), followed by fish cages (28.1%), prawn farming (9.4%), and mixed systems (6.3%).

In terms of experience, nearly 47% of aquaculture participants had been involved in the activity for 1 to 5 years. About 34% were relatively new, with less than one year of experience. In comparison, only 18.8% had practised aquaculture for more than five years, indicating that aquaculture is still an emerging livelihood option on the island.

Comparative Household Outcomes

To assess the impact of aquaculture, independent samples t-tests were conducted comparing key indicators between aquaculture and non-aquaculture households. The results are summarised in Table 1.

Table 1: Household Outcomes by Aquaculture Participation

Variable	**Aquaculture (n=32)**	**Non-Aquaculture (n=320)**	***t*-value**	***p*-value**
Monthly income (TZS)	35,200 (±12,400)	25,100 (±15,200)	3.21	0.002**
Food security score (1–5)	3.8 (±0.7)	3.1 (±0.9)	3.87	<0.001***
Dietary diversity score	4.2 (±1.1)	3.5 (±1.3)	2.68	0.009**
Children in school	2.1 (±1.0)	1.7 (±1.2)	1.65	0.102 (ns)

The results show that aquaculture households had significantly higher monthly incomes, better food security, and diets that are more diverse compared to non-aquaculture households. The difference in school attendance, however, was not statistically significant.

Income differences by aquaculture system

A one-way ANOVA revealed significant differences in income depending on the aquaculture system employed ($F = 4.56$, $p = 0.008$). Fish cage farming yielded the highest average income (TZS 41,300), while prawn farming reported the lowest (TZS 28,000).

Table 2: Mean Monthly Income by Aquaculture System

System	Mean Income (TZS)	Standard Deviation
Fish ponds	32,500	10,200
Fish cages	41,300	9,800
Prawn farming	28,000	7,500
Mixed	35,000	6,200

These findings suggest that technology type and system design may significantly influence economic returns in smallholder aquaculture.

Correlation between Aquaculture and Livelihood Outcomes

Correlation analysis further supported the positive relationship between aquaculture income and household well-being. Aquaculture income was **moderately correlated** with food security (r = 0.42, $p < 0.01$) and dietary diversity (r = 0.38, $p < 0.01$). Farming experience also had a weak but statistically significant correlation with income (r = 0.29, $p < 0.05$).

Table 3: Pearson Correlation Matrix

Variable	1	2	3	4	5
1. Aquaculture income	1.00				
2. Food security	0.42**	1.00			
3. Dietary diversity	0.38**	0.51***	1.00		
4. Farming experience	0.29*	0.17	0.22	1.00	
5. Household size	-0.08	-0.12	-0.05	0.14	1.00

Note: p <.05, < *.01*, < ***.001***

Predictors of aquaculture adoption

A logistic regression model was used to identify significant predictors of household participation in aquaculture. The model indicated that fishing income ($p = 0.016$), education level ($p = 0.032$), and land access ($p = 0.007$) were all statistically significant. Households with higher fishing income, better education, and access to land were more likely to adopt aquaculture.

Table 4: Logistic Regression: Predictors of Aquaculture Adoption

Predictor	B	SE	Wald	p-value	Odds Ratio
Fishing income	0.12	0.05	5.76	0.016*	1.13
Education level	0.45	0.21	4.59	0.032*	1.57
Land access	1.02	0.38	7.21	0.007**	2.77
Constant	-3.12	1.05	8.82	0.003	0.04

Reported Challenges in Aquaculture

Households practising aquaculture reported multiple challenges, the most significant being lack of capital (78.1%, $p < 0.001$), followed by poor quality feed (56.3%, $p = 0.002$), and predator threats (37.5%,

p = 0.040). Although water access was cited as a constraint (28.1%), it did not reach statistical significance.

Table 5: Challenges Reported by Aquaculture Households

Challenge	Frequency	Percentage	χ^2	p-value
Lack of capital	25	78.1	18.32	<0.001***
Poor quality feed	18	56.3	9.45	0.002**
Predators	12	37.5	4.21	0.040*
Water access	9	28.1	2.56	0.110

Qualitative Analysis Results

This section shares insights from interviews and focus group discussions held with aquaculture practitioners and key stakeholders across Pemba, Zanzibar. These conversations add essential depth to the numbers, highlighting the real-life motivations, challenges, and lived experiences of those involved in small-scale aquaculture.

i. Motivations for Adopting Aquaculture

Across the board, participants pointed to two main drivers: the need to diversify income and improve food security. Many shared how traditional fishing, once dependable, has become a gamble, mainly due to climate change and dwindling fish stocks.

One former fisherman summed it up:

"Before, I could go to sea and come back with enough fish to feed my family and sell. Now, some days I return empty-handed. With my fish pond, I always have something."

Another added:

"My children eat fish twice a week now, not just when I'm lucky with the nets."

These stories line up with the survey data showing higher food security among aquaculture households (see Table 1). The shift toward fish farming is not just a choice, but it is a response to uncertainty. For many, aquaculture offers something traditional fishing no longer can: consistency. Being able to harvest fish when needed, rather than hoping for a good catch, gives families both peace of mind and better nutrition.

ii. Perceived Benefits of Aquaculture

Beyond the economic benefits highlighted in the quantitative data, participants spoke about improvements in nutrition, daily routines, and overall well-being.

One mother shared:

"Even on days when we have no money, we can eat from the pond. My youngest was sick less after we started farming fish."

Women, in particular, appreciated the flexibility:

"I can feed the fish while caring for my children. I couldn't do that with fishing," said one woman.

In addition, for some families, the extra income made a real difference:

"Last year, my pond paid for my daughter's school uniform and books. Before, we had to borrow," a farmer in Chake Chake recalled.

These reflections help explain why aquaculture households scored higher in dietary diversity (Table 1). Being able to eat their fish means better nutrition and fewer trips to the market. Moreover, the money saved or earned can go toward other needs. The gender aspect stands out too: aquaculture opens doors for women in ways traditional fishing often does not.

iii. Systemic Challenges and Constraints

While the numbers pointed to financial constraints as a key barrier (Table 5), the interviews added input to that finding. One farmer put it bluntly:

"The feed alone costs more than I make some months. I tried to get a loan, but they wanted my house as collateral."

Others spoke about technical difficulties:

"Last season, all my fish died in one week. I still don't know why."

Then there is the market issue. As one farmer in Micheweni explained:

"Traders come and offer half the market price because they know I can't take the fish anywhere else."

These personal accounts give context to the broader data on adoption barriers (Table 4). Financial hurdles are not just about startup costs; operating a fishpond takes ongoing investment. In addition, when something goes wrong, many farmers lack the technical expertise to fix it. Limited market options further reduce the potential profits, no matter how well the fish are raised.

iv. Institutional Support and Community Perceptions

Local officials are aware of the promise aquaculture holds, but they also see the gaps. One agriculture officer put it like this:

"We train farmers, but then they have no access to quality fingerlings or feed. It's like teaching someone to drive without giving them a car."

On the community side, opinions were split, mostly along generational lines. Older fishers were often sceptical:

"This is not our way. The sea provides."

Younger fishers saw it differently:

"This is how we'll survive climate change," said a 28-year-old aquaculture adopter.

The relatively low adoption rate (9.1%) makes more sense in light of these perspectives. While training is happening, a lack of follow-through on inputs makes it hard for new farmers to succeed. Meanwhile, cultural resistance, especially among older generations, slows the pace of change. However, with younger people more open to innovation, adoption may rise over time.

v. What Farmers Want Moving Forward

When asked for solutions, participants did not hold back. Group purchasing was a popular idea:

"If we could buy feed as a group, it would be cheaper," one person suggested.

Many called for training that is more practical:

"Show us, don't just tell us," urged a woman from Wete.

Others looked to success stories:

"Mainland Tanzania has good models. We could learn from them," said a participant.

These suggestions echo many of the policy recommendations in the study's conclusion. Cooperative models could reduce costs and improve market power, while hands-on, demonstration-based training would likely be far more effective than lectures alone. Farmers do not just want knowledge; they want support that works in real-world settings.

Discussion

The findings of this study underscore the emerging significance of smallholder aquaculture in enhancing household well-being in coastal areas of Pemba, Zanzibar. Aquaculture-engaged households reported markedly higher income levels, improved food security, and diets that are more diverse compared to their non-aquaculture counterparts. These results are consistent with broader regional trends, where aquaculture is increasingly recognised as a livelihood diversification strategy that can mitigate the vulnerabilities of small-scale fishing communities (Shalli et al., 2024; Mulokozi et al., 2020).

The positive correlation between aquaculture income and both food security and dietary diversity reinforces the notion that income derived from aquaculture is not only used to meet basic economic needs but is also channelled into improved household nutrition. Similar findings have been reported in other East African contexts, where access to aquaculture has contributed to reductions in malnutrition and seasonal food shortages (Brodie et al., 2024; March & Failler, 2022).

Interestingly, the variation in income across different aquaculture systems points to a need for technological and infrastructural interventions. Fish cage farming, for instance, was associated with the highest average income, suggesting that targeted investment in such systems could yield higher returns. However, this also raises questions of equity and access, as more capital-intensive systems may be inaccessible to poorer households unless supported by subsidies, training, or cooperatives (Brugere et al., 2021).

The regression analysis further revealed that households with higher fishing income, greater educational attainment, and access to land were significantly more likely to adopt aquaculture. These findings highlight the role of socio-economic capital in influencing aquaculture uptake. Education, in particular, appears to enhance awareness, management practices, and openness to innovation, critical factors for navigating the technical demands of aquaculture (Mdoe et al., 2025; Regan et al., 2025).

Nevertheless, the study also reveals severe bottlenecks. The overwhelming majority of aquaculture practitioners reported challenges related to capital access and input quality issues, long documented in African aquaculture systems (Rege & Ochieng, 2022). Without adequate financial services, reliable feed supply chains, and institutional support, the scalability and sustainability of smallholder aquaculture remain at risk.

Additionally, the relatively recent engagement of most participants in aquaculture suggests that the sector in Zanzibar is still in a formative phase. This presents a unique opportunity for policy actors, development agencies, and research institutions to shape its growth trajectory. Aligning aquaculture development with climate resilience frameworks, blue economy strategies, and food sovereignty goals could transform not only livelihoods but also the environmental and nutritional landscapes of coastal communities (Makame et al., 2023; Newman et al., 2024).

Conclusion

This study has demonstrated that smallholder aquaculture offers substantial benefits for income generation, food security, and dietary diversity among households in Pemba, Zanzibar. Households

engaged in aquaculture consistently reported improved socio-economic outcomes compared to those relying solely on traditional fishing or other livelihoods. These findings position aquaculture as a promising and increasingly vital strategy for enhancing rural resilience, particularly in coastal communities grappling with the twin pressures of climate change and declining marine resources.

Despite its potential, the study also highlights several structural and capacity-related challenges that limit the growth and impact of smallholder aquaculture. Inadequate access to capital, shortage of technical expertise, and unreliable input supply chains, particularly in terms of quality feed and fingerlings, remain significant barriers to entry and sustainability. Limited institutional support and underdeveloped market linkages compound these constraints, which collectively undermine the sector's scalability.

To unlock the full potential of smallholder aquaculture, a multi-faceted approach is required. There is a need for the development of inclusive microfinance schemes tailored to the specific needs of aquaculture practitioners, with a particular focus on supporting women and youth. Strengthening extension services to provide technical training, system-specific guidance, and adaptive management support is equally critical. Moreover, fostering public–private partnerships can help stabilise and expand access to essential aquaculture inputs. Lastly, integrating smallholder aquaculture into broader food security, climate resilience, and blue economy strategies will ensure it is not merely a supplementary livelihood but a central pillar in sustainable development planning.

If these measures are systematically implemented, smallholder aquaculture in Zanzibar and more broadly across East Africa can evolve into a transformative force, contributing meaningfully to household well-being, ecological sustainability, and regional food sovereignty.

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