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Research Article

Coastal Mariculture: Status, challenges, and future perspectives of Milkfish (*Chanos chanos*) farming in Tanzania

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Abstract

An investigative field survey was performed from October to November 2023 at nine villages within five districts in four selected regions, aimed to assess the status, challenges, and future perspectives of coastal mariculture development along the coastline in Mainland Tanzania. During this study, both purposive and snowball sampling techniques were used. A structured questionnaire forms were used as an assessment tool to gather fish farmers's information, followed by a focussed group discussion and key informants' interviews with government officials. A total of 162 fish farmers, government officials and animal feed sellers were assessed. Demographic data indicated that most farmers were male accounting for 67.9% and females (32.5), aged between between 20 and 40 years old (56.8%), with primary education level, accounted for 82.7%. On the other hand, milkfish were mostly stocked at 2-3 fish/m^2 in an earthen pond system, and under monoculture were mostly fed local feed ingredients (88%). The study showed that three major income-generating activities: Milkfish (85%), crab fattening (12%), tilapia (2%), and sea cucumber (1%) were practiced along the coast to support blue economy initiatives. Additionally, the results indicated that government subsidies (89), farm inputs (81%), and capital investment were the major challenges that constrained milkfish development along the coastline of mainland Tanzania. Further, current data indicated that milkfish farming is solely practiced at the subsistence level and needs a scale-up to sustain the blue economy. The present study highlighted the status, challenges, and plan for the future development of coastal mariculture in Tanzania.

Introduction

The world population is projected at 9.7 billion by 2050 implying an increased need for food and nutritional security and other nutritional systems. Fish farming is the ultimate solution to food and nutritional security and other nutrition gaps, poverty alleviation and overall shared prosperity in the world. The development of the sector has proved to be two to four times more effective in transforming lives among the populous rural communities. In Tanzania, fish farming has a pitfall history, characterized by marginal vacillated production from the 1960s to 2010s (Mmanda *et al*., 2020). It has been hampered by low technology, poor management practices, inadequate quality fish feeds and seeds supply, lack of investment capital, and pitiable recognition in the governmental development plans (Kaliba *et al*., 2006; Mmanda *et al*., 2020). In recent years, however, the government of Tanzania through the Directorate of Aquaculture Division (DAQ) set some sectoral and cross-sectoral reforms to uplift the aquaculture sector. This has enabled DAQ to a make consolidated effort under National Aquaculture Development Strategy (NADS) to address issues that have been identified as the key factors for sustainable aquaculture development. Some of the issues addressed by NADS include; promoting the production of affordable quality fish seeds and feed, strengthening mariculture extension services, and enhancing commercial aquaculture production (URT, 2009). Moreover, NADS addressed policy, legal, and institutional framework to accommodate the new emerging technologies and farming techniques for the development aquaculture industry in the country including cage farming technology (URT, 2019). Moreover, the role of the Ministry responsible for fisheries and aquaculture development is to formulate policy, strategy, programs/projects, laws, and regulations, establish guidelines, promote investments and regulate the fisheries sector were also highlighted in the fisheries policy of 2015 (URT, 2015). The Ministry also developed and implemented mariculture investment guidelines through the South West Indian Ocean Fisheries Governance and Shared Growth Program (SWIOFish) in 2015. This guideline has promoted investment in mariculture operations along the coast of Tanzania, particularly in seaweed farming, oyster sea ranching, crab fattening, and prawn farming in the Southern regions (URT, 2021).

The fish farming sector particularly milkfish farming has been receiving support from various external sources including the Aquaculture for Local Community Development Programme (ALCOM) under the Food and Agriculture Organization (Wetengere, 2000), the Norwegian Agency of Development Cooperation (NORAD; www.ifad.org), World Vision Programmes (Mwanzo Project, www.wvi.org/tanzania), Heifer international just to mention a few. These efforts have brought a significant change in inland aquaculture and not in mariculture operations. Recently, FAO built a huge hatchery in Zanzibar to make access to fingerlings easier. Yet, these efforts have not brought significant growth in marine fish farming. Using coastal waters for fish farming through cage and pond culture is possible, yet the technology has not been utilized in coastal environments. In fact, cage aquaculture is generally considered one of the most promising ways to achieve several targets of the United Nations sustainable development goals (SDGs) and blue economic development (Choudhary *et al.*, 2021; Hossain *et al.*, 2021).

The country has an extensive coastline of more than 1400 km, extending from Tanga bordering Kenya to Mtwara where the country borders Mozambique. Likewise, the two Islands of Zanzibar Unguja and Pemba and other small islands like Mafia have extensive coastline potential for fish farming. However, mariculture operations in the coastal areas have lost their popularity over several decades after the donor's project phased out. In recent years, the number of milkfish farmers dropped promptly from 5000 fishponds to an unknown number (URT, 2015), which required un urgent research findings for further government development strategic plans and action. Therefore, this study aims to enhance the blue economy and mitigate climate change through mariculture practices in Tanzania.

Materials and methods

Study sites

The study was carried out in nine villages within five districts in four regions of mainland Tanzania from October to November 2023. The study sites were located between latitude -10°17' and -5°06' and longitude 38°30' and 40°11' and were selected purposively based on the area with large numbers of active milkfish farmers and local feed ingredients (Fig. 1).

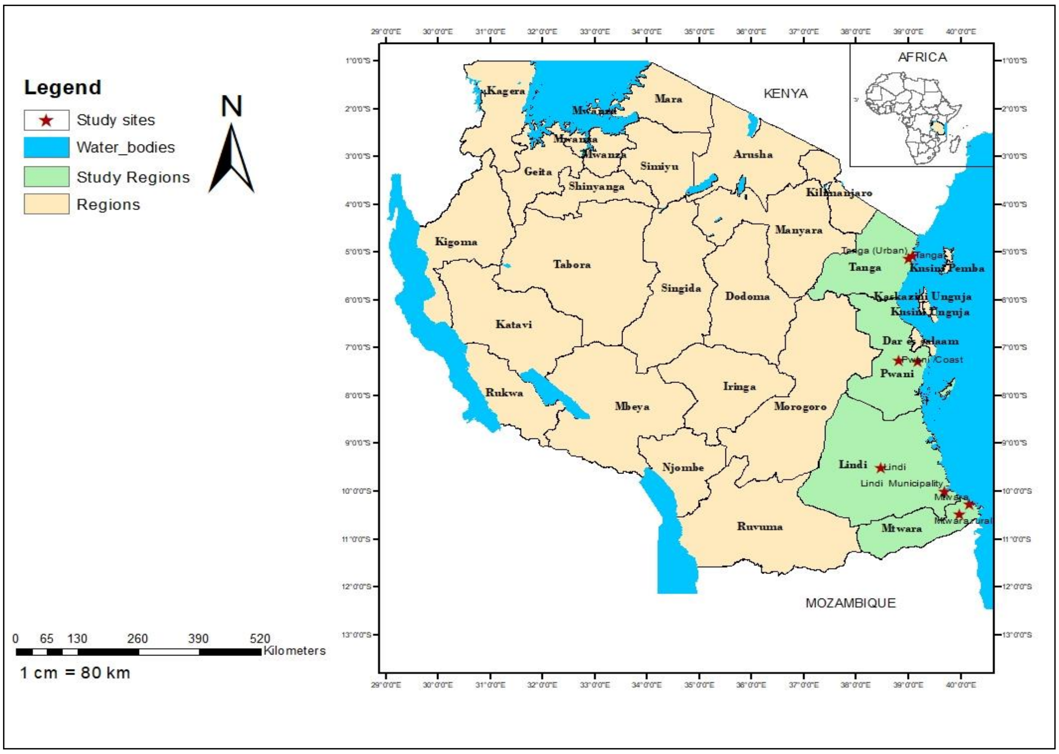

Figure 1: Map of Tanzania showing the study sites (modified from ArcGIS Desktop, version 10.8, IMS Database, 2024).

The average temperature along the coast and in the offshore Islands of Tanzania ranged between 27°C and 29°C, while the annual rainfall ranged from 1029 to 1879 mm. According to the human population census done in Tanzania in 2022 indicated that nearly 16 million people live along the coastline of Tanzania and they are relying on the coastal resources for their livelihood (URT, 2022). The main economic activities at the study sites are tourism, mining, fishing, agriculture, and animal production.

Data and sample collection

A structured questionnaire form comprising questions concerning social demographic characteristics (sex, age, and education level) of fish farmers, and fish farm characteristics (location, size, farm ownership, and farming periods). Other factors considered in the questionnaire were farming system, farming methods and production, feedstuffs used, source of fish seeds, stocking density, feeding practices, cost of feeds, type, and sources of water used on the farm, challenges facing milkfish farming operations and any other issues relating to milkfish farming was used to collect data. In this study, both snowball and purposive sampling techniques and approaches including Focus group discussion, key informants' interview, round table discussion and on-site visits were deployed.

Data analysis

The observational data collected during the study were analyzed using Origin lab software, OriginPro 2024b (version 10.15). Descriptive statistics were run based on cross-tabulation to obtain frequencies and percentages for multiple comparisons of variables. Differences between variables were based on Chi-square analysis and a significance level of 5%.

Results

Demographic characteristics of respondents

In total, 162 milkfish farmers, local fish feed producers, and milkfish fingerlings collectors (respondents) in mainland Tanzania were surveyed. The majority of respondents (54.3%) were located in Mtwara region, followed by Lindi region (24.5%), while the lowest respondents (9.2%) were reported in Pwani region. Overall, the majority of respondents involved in Milkfish farming were males (67.9%). However, the proportion of males and females involved in the milkfish farming operations varied significantly (p=0.0064) from one region to another (Table 1). The proportion of female respondents involved in milkfish farming activities was 32.1%, but the figure ranged from 43.1% in Mtwara to 13.3% in Pwani (Coastal) region. This study indicated that the age of most milkfish farmers (56.8%) ranged between 20 and 40 years old, followed by age group ranged from 40 to 60 years (35.2%) and 7.4 % for farmers aged>60 years. Overall, most of the farmers (82.7%) had finished primary education level, followed by secondary education (8%) and tertiary (6.2%), refer to Table 2. However, the education level within age-group did not vary significantly (p=0.1275), whereby the highest proportion of participants with primary (80.4%), secondary (9.8%), and tertiary (8.7%) education were reported in an age-group between 20 to 40 years (Table 2).

Table 1: Gender distribution of respondents at the study sites. Figures in brackets indicate the percentage of respondents of each gender within regions and between regions (total).

Region	Gender (Sex)			
	Female	Male	Total	Chi-square
Lindi	7 (16.3)	36 (83.7)	43 (26.5)	P = 0.0064
Mtwara	38 (43.1)	50 (56.8)	88 (54.3)	
Pwani	2 (13.3)	13 (86.7)	15 (9.2)	
Tanga	5 (31.2)	11 (68.8)	16 (9.9)	
Total	52 (32.1)	110 (67.9)	162 (100.0)	

Table 2: Age groups (years) and education level of respondents at the study sites. Figures in brackets indicate the percentage of respondents in the education level within age groups, and between age groups (total).

Age group	Education Level					
	None	Primary	Secondary	Tertiary	Total	Chi-square
< 20	0 (0.0)	1(100)	0 (0.0)	0 (0.0)	1 (0.6)	
20-40	1 (1.1)	74 (80.4)	9 (9.8)	8 (8.7)	92 (56.8)	
40-60	1 (1.8)	49 (86.0)	4 (7.0)	3 (5.3)	57 (35.2)	P = 0.1275
> 60	2 (16.7)	10 (83.3)	0 (0.0)	0 (0.0)	12 (7.4)	
Total	4 (2.5)	134 (82.7)	13 (8.0)	11 (6.8)	162 (100.0)	

Characteristics of tilapia fish farming

The majority of the fish farms (n=162) were owned by individuals (93.2%), followed by farmer's group (6.2%) and private companies which accounted for 0.6% (Fig. 2). The milkfish farming systems were dominated by earthen ponds (98.8%), followed by concrete tanks (1.2%) (Table 3). The average pond area was 1399 m^2 and fish farm size ranged from 300 to 9000 m^2, with a depth of 0.8 to 2 m for earthen, while the average size of concrete tanks was 40 m^3, with a dimension of 4×5×1 m.

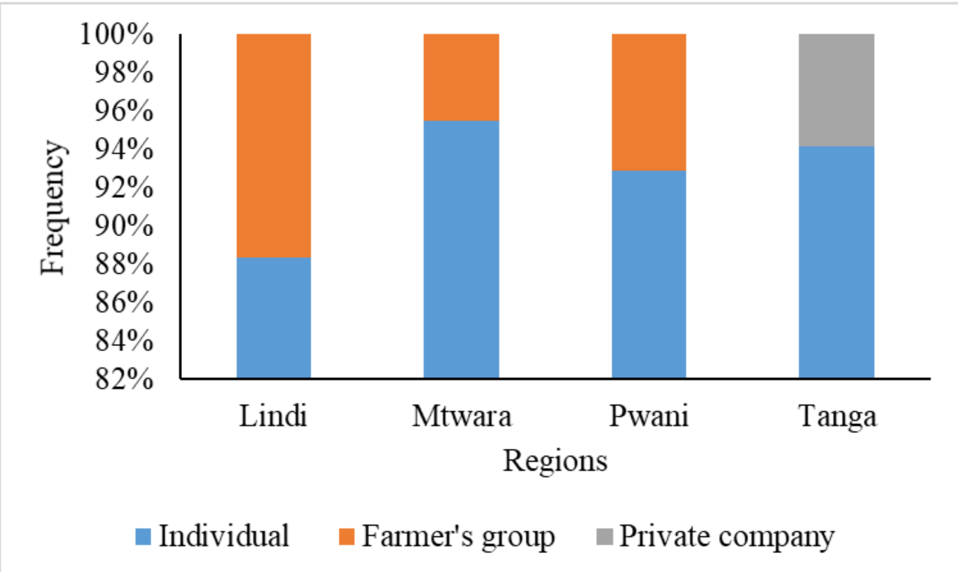

Figure 2: Fish farm ownership at the study sites.

Table 3: Cultural systems and fish farm ownership. Figures in brackets indicate the percentage of fish farm ownership within fish farming type, and fish farming type overall (total).

Culture system	Fish farm ownership				
	Individual	**Farmer's group**	**Private company**	**Total**	**Chi-square**
Earthen pond	149 (93.1)	10 (6.3)	1 (0.6)	160 (98.8)	P = 0.9289
Concrete tank	2 (100)	0 (0.0)	0 (0.0)	2 (1.2)	
Total	151 (93.2)	10 (6.2)	1 (0.6)	162 (100)	

Earthen ponds were the dominating fish farming system in the entire study sites (98.8%), however, its distribution varied significantly (p<0.0000) within the regions, whereby Lindi accounted for 26.5%, 54.3% for Mtwara, Pwani (9.3%), and Tanga (9.9%). Other cultural systems like concrete tanks were found only in the Tanga region (Table 4).

Table 4: Regional distribution of fish farming systems. Figures in brackets indicate the percentage of fish farms within each region, and fish farms overall (total).

Region	Fish farming systems			
	Earthen ponds	**Concrete tanks**	**Total**	**Chi-square**
Lindi	43 (100)	0 (0.0)	43 (26.5)	P < 0.0000
Mtwara	88 (100)	0 (0.0)	88 (54.3)	
Pwani	15 (100)	0 (0.0)	15 (9.3)	
Tanga	14 (87.5)	2 (1.2)	16 (9.9)	
Total	160 (98.8)	2 (1.2)	162 (100)	

Milkfish was the most cultured fish species (85%), followed by mixed cultures of crab fattening (12%), tilapia (2%) and sea cucumber (1%), refer to Figure 3.

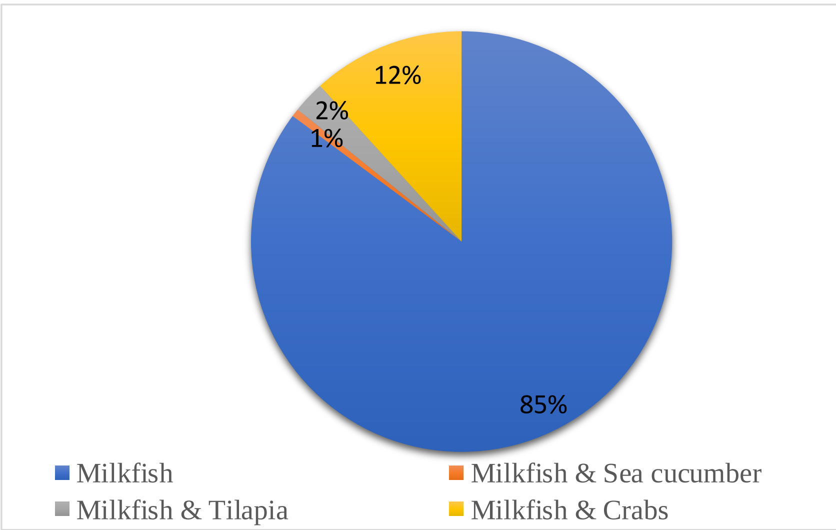

Figure 3: Commonly cultured fish species at the study sites.

The cultured fish were mostly (90%) raised semi-intensively under monoculture systems (Table 5). The stocking density varied from one region to another (p<0.0001), with most fish stocked at a rate of 3 fish/m^2 (66.7%), followed by 2 fish/m^2 (17.9%) and 5 fish/m^2 (Table 6). There was a great variation in the culture period to market size and the stocking density with no clear pattern linking stocking density to culture period and market size (Table 7).

Table 5: Cultural practices and production systems. Figures in brackets indicate the percentage of respondents' production systems within culture practices, and culture practices overall (total).

Culture practices	Production system				
	Extensive	Intensive	Semi-intensive	Total	Chi-square
Monoculture	16(10.0)	0 (0.0)	144 (90.0)	160 (98.8.0)	$P = 0.6376$
Polyculture	0 (0.0)	0 (0.0)	2 (100)	2 (1.2)	
Total	16 (9.9)	0 (0.0)	146 (90.1)	162 (100.0)	

Table 6: Fish stocking density (fish/m^2) at the study sites. Figures in brackets indicate the percentage of respondents' stocking density within the region, and stocking density overall (total)

Region	2	3	5	>5	Total	Chi-square
Lindi	3 (6.9)	15 (34.9)	23 (53.5)	2 (4.7)	43 (26.5)	
Mtwara	0 (0.0)	88 (100)	0 (0.0)	0 (0.0)	88 (54.3)	
Pwani	10 (34.5)	5 (4.6)	0 (0.0)	0 (0.0)	15 (9.3)	$P < 0.0001$
Tanga	16 (100)	0 (0.0)	0 (0.0)	0 (0.0)	16 (9.9)	
Total	29 (17.9)	108 (66.7)	23 (14.2)	2 (1.2)	162 (100)	

Table 7: Stocking density and culture period of Milkfish *Chanos Chanos* per production cycle. Figures in brackets indicate the percentage of respondents within stocking density and stocking density in total.

Stocking density, fish/m^2	Culture period, months						
	6	7	8	9	≥10	Total	Chi-square
2	1(3.4)	27 (93.1)	0 (0.0)	0 (0.0)	1 (3.4)	29 (17.9)	
3	0 (0.0)	88 (81.5)	19 (17.6)	1 (0.9)	0 (0.0)	108 (66.7)	
5	0 (0.0)	21 (91.3)	1 (4.3)	1 (4.3)	0 (0.0)	23 (14.2)	
6	0 (0.0)	1 (100)	0 (0.0)	0 (5.9)	0 (0.0)	1 (0.6)	$P = 0.2479$
≥7	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.6)	
Total	1 (0.6)	138 (85.2)	20 (12.3)	2 (1.2)	1 (0.6)	162 (100)	

Local feed ingredients used by fish farmers

We found that more than 88% of respondents relied on locally available feed ingredients as a major feed supplement for their cultured fish (Fig. 4). However, the local feed ingredients used at the study sites varied ($p<0.0001$) from one region to another depending on availability. Feed ingredients availability was determined by factors such as production season, climatic conditions, geographical zone, and accessibility. The most commonly used local feed ingredients were maize bran, followed by anchovy, marine shrimps, sunflower seed cake, and wheat pollard (Fig. 5).

Challenges associated with milkfish farming in Tanzania

The development of the milkfish industry along the coast of Tanzania is constrained with several challenges despite the past government efforts, huge water resources, manpower, and locally available feed ingredients the country have. The result of the present study showed that the milkfish farming operations along the coast of

Tanzania were mainly constrained by the availability of farm inputs, government subsidies, investment capital, and extension (Fig. 6).

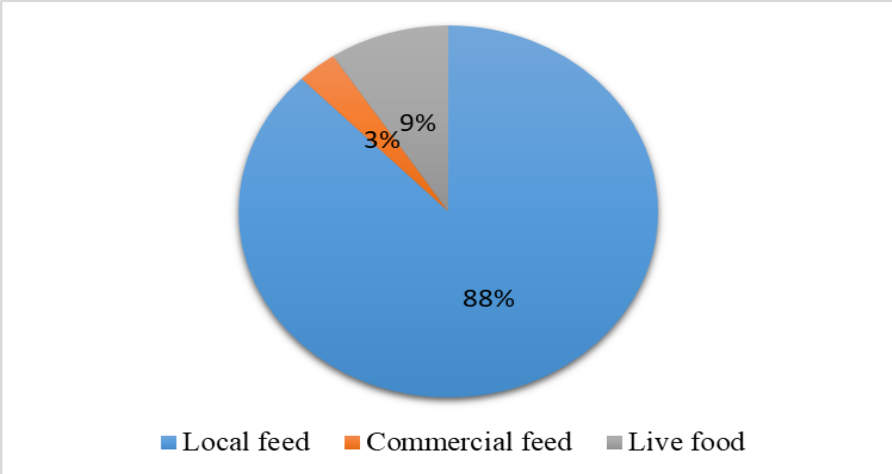

Figure 4: Common feedstuffs fed to cultured species in the study sites.

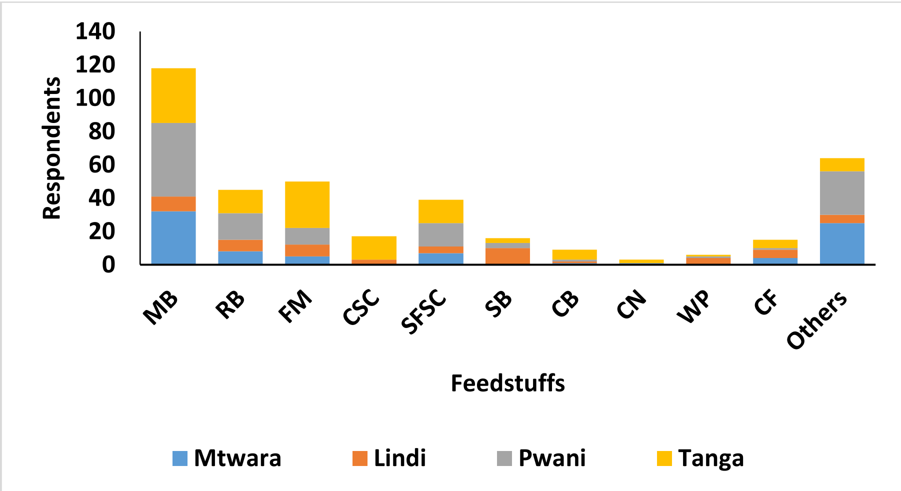

Figure 5: Commonly used local feed ingredients in the study sites.

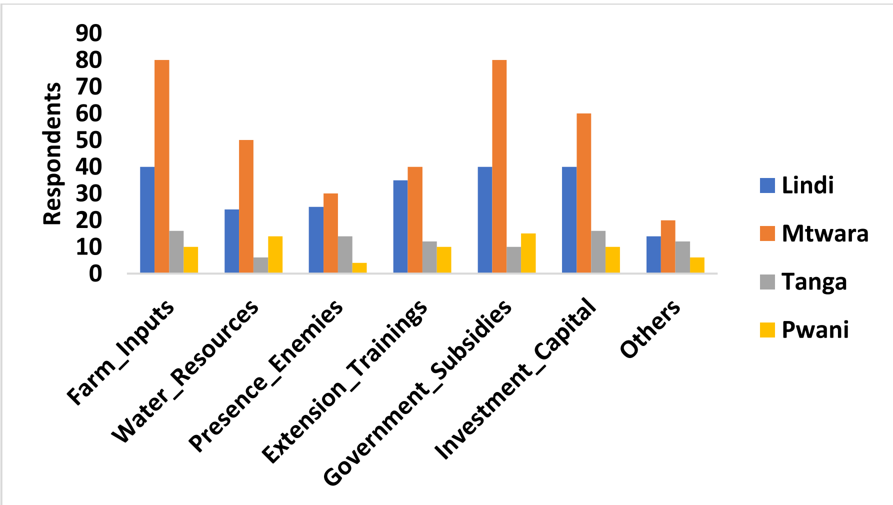

Figure 6: Level of constraints affecting the development of coastal mariculture.

Discussion

Milkfish (*Chanos chanos*) farming has demonstrated its potential as a sustainable and economically viable aquaculture practice in different countries in the world including Tanzania (Mmochi, 2016; Sigalla and Shalli, 2023). Milkfish farming operations have significantly contributed to the socio-economic and livelihoods of coastal communities in Tanzania, promoting a sustainable blue economy in the region (Mwangamilo and Jiddawi, 2003; Mirera, 2019). This form of aquaculture supports food security, provides a reliable source of protein, and diversifies income streams, which helps to combat poverty and reduce inequality. In addition, Milkfish farming operations are one of the economic activities that have contributed to the National development goals concerning poverty alleviation and enhanced food security in Tanzania (Sullivan *et al.*, 2007). At the moment, Milkfish farmers who are engaged in milkfish farming operations benefit from increased household income and improved economic stability, which supports overall community development.

A total of 162 milkfish farmers, comprised of local fish feed producers and milkfish fingerlings collectors in three regions in mainland Tanzania were surveyed. Overall, the majority of stakeholders in the study sites who engaged in milkfish farming operations were male (68%). A similar proportion of engagement of males in fish farming operations was reported by Githukia *et al.* (2020) who reported that gender participation in different mode of aquaculture value chain in the Western Kenya communities to be high to men, accounted for 68% compared to women (32%). Additionally, the findings of previous studies indicated that male owned about 60 to 100% of the aqua-farms (Olanike and Gbenga, 2013; Tran *et al.*, 2020; Omeje *et al.*, 2020; Subasinghe *et al.*, 2021; Adam and Njogu, 2023). According to these findings, males accounted for 85% of the fish farmers in Nigeria (Tran *et al.*, 2020), 80% of fish farmers in Ondo state, Nigeria (Olanike and Gbenga, 2013), and 70% of the 500 input providers in Nigeria (Subasinghe *et al.*, 2021). On the contrary, the low participation of males in aquaculture operations was reported in previous studies in different places worldwide (Hishamunda *et al.*, 2014; FAO, 2014; Kruijssen *et al.,* 2018). The proportion of female respondents involved in milkfish farming activities was 32.1%, but the figure ranged from 43.1% in Mtwara to 13.3% in Pwani (Coastal) region. A previous study reported that the social and economic drivers that control whether farmers practice aquaculture as a livelihood option include among other things, gender, social network strength, material style of life, and the time available for a supplementary livelihood (Mirera, 2019). In the current study, the proportion of males and females involved in the milkfish farming operations varied significantly from one region to another in Tanzania. Similar findings were reported in the previous studies in different countries in the African continent and across the globe (FAO, 2014; Jahan *et al.*, 2015). In many tribal cultures in Tanzania, women are expected to perform reproductive roles and to take responsibility for household management, food provisioning and nursing tasks, which hinders their ability to participate in paid economic activities. Equal gender participation helps to increase aquaculture productivity (Jahan *et al.*, 2010) and fish consumption within the household (Heck *et al.*, 2007; Jahan *et al.*, 2010). In Vietnam, aquaculture operations particularly in the areas of marketing, feeding fish, and applying fertiliser on ponds are mainly practiced by women whose roles are significantly higher although, they are not involved in any activity without the support from the men.

Regarding the age of respondents, the findings of the present study revealed that the age of most milkfish farmers were between 20 and 40 years old which was equivalent to 56.8%, while those age groups ranging from 40 to 60 years were 35.2% and 7.4% for aged group> 60 years, refer Table 2. Similar proportional findings were reported in previous studies in Nile tilapia farming carried out by other researchers in Tanzania (Chenyambuga *et al.*, 2014; Mwaijande and Lugendo 2015; Athirah *et al.*, 2020; Mmanda *et al.*, 2020; Mulokozi *et al.*, 2020). On the other hand, most of the farmers (82.7%) had finished primary education level, followed by secondary education (8%) and tertiary (6.2%). The education level within age-group did not vary significantly (p=0.1275), whereby the highest proportion of participants with primary (80.4%), secondary (9.8%), and tertiary (8.7%) education were found in the age-group between 20 to 40 years. Inconsistency, a similar high proportion of fish farmers with primary education were also reported in previous studies in aquaculture worldwide (Adhikary *et al.*, 2018; Mmanda *et al.*, 2020; Mulokozi *et al.*, 2020). This phenomenon showed that the majority of stakeholders with informal or lower-level education relied on fish farming operations particularly milkfish farming as an alternative economic activity for their sustainable social-economy and improved livelihoods. For the farm ownership, the majority of fish farms held by milkfish farmers were owned individually (93.2%), while farmer's group and private owned accounted for 6.2% and 0.6%, respectively. Similar findings were reported in previous studies elsewhere worldwide (Chenyambuga *et al.*, 2014; Mmanda *et al.*, 2020). These social-demographic characteristics data are very important in any production and it has been reported to positively influence milkfish farming practices.

Milkfish farming is one of the most common types of mariculture activity practiced along the coast of East Africa particularly in Kenya, compared to seaweeds, artemia, mud crab, or prawn farming (Mirera, 2019). Milkfish farming is mostly farmed in the intertidal mangrove flats. In our study Milkfish was the most marine cultured fish species (85%) along the coastline Indian Ocean of Tanzania, followed by mixed cultures of crab fattening (12%), tilapia (2%), and sea cucumber (1%). The cultured fish were mostly (90%) raised semi-intensively under monoculture systems. The most dominant farming system in the study sites was the pond culture system, which accounted for 98.8% of the total farming systems used, with a farm size ranging from 300 to 9000 m^2 and a depth of 1 to 2 m. On the contrary, a lower size range of milkfish farms from

120 to 1200 m^2 was reported in Western Counties of Kenya (Mirera, 2019).

The stocking density varied from one region to another, with most fish stocked at a rate of 3 fish/m^2 (66.7%), followed by 2 fish/m^2 (17.9%) and 5 fish/m^2. The culture period reported in the present study mainly ranged between 6 to 8 months. There was a great variation in the culture period to market size and the stocking density with no clear pattern linking stocking density to culture period and market size. A similar low stocking density in milkfish farms were reported in previous literature (FAO, 2009; Mirera, 2011). Additionally, low to medium stocking density of 5 to 10, fish /m^2 and high density of 15 to 20 fish /m^2 were reported in milkfish farms by FAO (2009). This is because fish productivity increases with the number of fingerlings stocked (Islam *et al.*, 2023) and stocking density is reported to be positively correlated to yield (Shoko *et al.*, 2016). Literature shows that a unit increase in the number of fingerlings stocked in a milkfish pond increases by 0.026 kg of fish harvest (Fortes and Pinosa, 2007).

In the present study, the majority of milkfish farmers accounting for 88% of milkfish practitioners relied on locally available feed ingredients as a major feed supplement for their cultured fish, something that lowers production. Overall, the local feeds applied in the study area varied significantly from one region to another. Additionally, the production of fish feeds locally and their inadequate nutrient content hinders fish production. Locally available feed ingredients include maize bran, anchovy, marine shrimps, sunflower seed cake, and wheat pollard. Similar findings were reported in previous studies (Chenyambuga *et al.*, 2014; Mmanda *et al.*, 2020). Similarly, the majority of milkfish farmers are relying on wild-caught fish seed (data not presented), leading to the inability to stock ponds at appropriate stocking densities. Similar findings were reported by Mirera (2019). On the other hand, according to the present study, the average weight at harvest was 300 g, which the value range was consistent with the report by FAO (2009) in which a market size ranged from 250 to 300 g. However, the market size of fish is generally determined by consumer preference, hence the domestic or regional average market size for milkfish varies from region to region and within the country (FAO, 2009). Therefore, the most preferred market size in Tanzania's local market ranged from 200 to 300 g.

The sustainability of milkfish farming is also supported by community-based management approaches. These approaches involve local communities in decision-making processes and resource management as well as needs assessment for sustainable socio-economy and improved livelihoods, ensuring that the benefits of milkfish farming are equitably distributed. The assessment of rural aquaculture in selected districts indicates that milkfish farming provides a reliable source of income, which helps in diversifying the economic activities of farming households (Mmochi, 2016; Shalli *et al*., 2024). Moreover, the potential for expanding milkfish farming to new areas without causing significant ecological disruption makes it a viable option for sustainable economic development. The diversification of aquaculture through *Chanos chanos* farming is crucial for reducing economic vulnerability, and enhancing resilience against economic shocks and climatic changes (Engle and Senten, 2022). Moreover, there is growing recognition that sustainable aquaculture can contribute significantly in addressing global food and nutritional insecurity, economic, and environmental challenges (Naylor, 2021; FAO, 2024).

In Tanzania, milkfish farming has been recognized for its substantial contribution to household incomes and community livelihood improvements as well as improved local economies (Shalli *et al.*, 2024). By addressing the challenges and leveraging the opportunities, milkfish farming can play a crucial role in supporting a sustainable blue economy, ensuring food and nutritional insecurity (Mmanda *et al.*, 2020; Mulokozi *et al.*, 2020; Shalli *et al.*, 2024). The sustainability of milkfish farming depends on continued support from governments, non-governmental organizations, and other stakeholders. Milkfish has progressively increased in terms of quantity produced and area farmed, while production per unit area is still low (Mirera, 2019). Farming is practiced at the subsistence level, and extensively, contributing more to the food and nutrition security of the communities, rather than to economic gains. This venture needs to be scaled up for economic benefits. In Tanzania, milkfish farming which was mainly supported by external funding sources has ceased (Mayowela-unpublished), therefore needs government subsidies and other development initiative via the blue economy agenda. The milkfish in Mtwara and other regions are approaching stagnation in terms of production, despite continued efforts from ecosystems conservational organizations and the government mainly due to available technical support and feedstuffs experts. Furthermore, in this study, the analysis of the economics of rural, small-scale milkfish farming was conducted to understand the current status and future plans to enhance the milkfish sector. With the enhanced production and availability of input supplies (mainly seed and feed), it is suggested that the milkfish industry can economically provide sufficient feed and income requirements to local fish farmers and improve coastal ecology.

The development of the milkfish industry along the coast of Tanzania is constrained by several challenges despite the huge suitable areas for fish farming extended to up to 1474 m long coastline along the Indian Ocean, clear and safe water resources, availability of wild milkfish fingerlings and local feedstuffs. The government efforts, huge water resources, local market, manpower, and locally available feedstuffs in the country are expected to progressively enhance the aquaculture in Tanzania. However, in the present study, several factors were identified as a hindrance to milkfish production and sustainability. Among these factors, include Furthermore, availability of farm inputs, government subsidies, investment capital and extension services, education, and seeds. The farm inputs, capital, and government subsidies contributed more than 80% of the problem. In the four regions studied, Lind and Mtwara were found to be most affected by a lack of government subsidies, capital, water resources and extension training services. The dissemination of improper knowledge and skills from fellow farmers has highly impacted negatively farming operations along the coastal areas of Tanzania. For example, knowledge on stocking density and farming period was found to be uniform in the entire district and region of study According to Shalli *et al.* (2024) have reported that the production of milkfish is positively related to the number of fingerlings stocked, and pond fertilization. In the study area, lack of pond fertilization or artificial feeding was a huge setback to production. Elsewhere, natural population growth in the coastal areas experiences significant immigration due to the diverse livelihood opportunities like fishing, tourism, markets, and business. Additionally, most of the coastal communities largely depend on small-scale capture fisheries which in return resulted over exploitation, hence leading to a decline in population stocks (Mangi and Roberts, 2006). In addition, the presence of a reliable market in middle-class populations, the decline in wild stocks population, and the advancement of farming methods and technologies, all together were considered among the factors which enhanced aquaculture development in Africa (Hecht, 2006; Tschirley et al., 2015).

For the future development of coastal mariculture, the government and coastal community must work together hand to hand in the utilizing of blue economy resources and resource opportunities for their sustainable social economic development and livelihood improvement. The development should be associated with empowering the available hatcheries for sustainable milkfish fingerlings production. In addition, it's necessary to assess the existing extension frameworks and provide appropriate options that can address the existing challenges of low production, dependence on wild fingerlings, and dependency on donor funds to enhance milkfish farming production.

Conclusions

This study informed us about the current status of milkfish farming practices and distribution of farming systems for government data collection and policy making and implementation as well as challenges causing the decline of milkfish operations along the coastal regions of Tanzania. Demographic Social demographic characteristics have shown gender participation and their contribution to the development of the coastal community economy and livelihood improvement. In addition, the findings have indicated the need for capacity building on gender inclusion in income-generating activities along the coastal region. The feed data has provided a platform for advocating the need to develop artificial fish feeds as feeding strategies for cultured *Chanos chanos* based on locally available feed ingredients. The information obtained in this study is urgently needed to expand the milkfish operation in the country, increase benefits associated with milkfish, and ensure sustainability. Generally, milkfish farming needs to be scaled up for blue economic enhancement since the current farming is mainly practiced at the subsistence level.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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