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Research article

Determinants of fish catch and post-harvest fish spoilage in small-scale marine fisheries in the Bagamoyo district, Tanzania

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ABSTRACT

The fisheries sector of Tanzania is dominated by small-scale fishers who produce up to 95% of the total amount of fish caught in the country. The small-scale fisheries are constrained by inadequate infrastructure, including a lack of capacity for processing and cold storage facilities, poor transportation and fishing tools that increase post-harvest losses. Small-scale fishers lack sufficient capital and skills to invest in modern fishing technologies. Additionally, social-demographic aspects of the fishers, such as education level, gender, age, fishing experience and training influence access to fishing resources and capital, leading to variation in fish catch and post-harvest losses. Thus, this study examined factors that influence fish catch and spoilage in small-scale fisheries in the Bagamoyo District, Tanzania. Forty randomly selected fishers from the Mlingotini fishing village were interviewed. The results show that after spending an average of 11 h per fishing session, the fishers catch an average of 18.5 kg of fish. The amount of fish captured differed with fishing experience, age and sex of the fisher, education level of the fisher, and the time spent selling the captured fish. On average, 10% of the weight of the fish captured per fishing session spoils. The level of spoilage varied according to the fisher's age and sex, education level, fishing experience, length of fishing session, and fishing gear used. Provision of training related to fish processing and handling and improvement of cold storage and transport facilities are recommended to reduce spoilage.

1. Introduction

Small-scale fisheries (SSF) in developing countries play a vital role in contributing to food and livelihood security, poverty reduction, and rural development (Sowman, 2006; Akande and Diei-Ouadi, 2010). Fish is an important source of protein, especially where other sources of animal protein are scarce or expensive (Béné and Heck, 2005). The SSF provides 32% of animal protein consumed in Africa, rising to 70% in coastal areas (Gyan et al., 2020; Arthur et al., 2022). In addition, the SSF creates household income that increases access to other sources of food (Béné and Heck, 2005; Obiero et al., 2019). In Africa, SSF contributes over 60% of the fish supply to domestic and regional markets (Akande and Diei-Ouadi, 2010). However, post-harvest activities of SSF often receive less attention within the fisheries value chain despite being a critical component of livelihood (Sowman, 2006; Gyan et al., 2020; Akintola et al., 2022). The SSF are characterised by low technology, labour-intensive fishing activities, and relatively low capital investments (Sowman, 2006). Fishers use artisanal fishing tools and operate small un-motorized vessels, which prolong fishing sessions and increase post-harvest loss (Jiddawi and Öhman, 2002; Sowman, 2006).

Fish is an extremely perishable food commodity with serious losses due to spoilage, from harvest to consumption (Maulu et al., 2020). Small-scale fish catches pass through many hands from harvest to consumption, increasing spoilage (Akande and Diei-Ouadi, 2010). Fish traders visit different fish landing sites to buy fish and transport them to markets in major towns (Hamidu, 2014). It has been estimated that 10% of the world's fish catch is lost due to poor handling, processing, storage and distribution (Maulu et al., 2020). The losses in small-scale fisheries are particularly high (Gyan et al., 2020; Kaminski et al., 2020). Tanzania and Uganda experience up to a 40% physical loss of sardines, *Rastrineobola argentea* (Akande and Diei-Ouadi, 2010). The quick spoilage of fish is caused by both intrinsic and extrinsic factors (Ghaly et al., 2010). The fishing method, fish species, sanitation, processing and storage conditions influence microbial spoilage (Tesfay and Teferi, 2017; Gyan et al., 2020). Poor handling and delayed evisceration and icing of the fish increases microbial contamination and spoilage (Ikape, 2017). Fish guts harbour spoilage bacteria and spoilage enzymes that attack the flesh of the fish after death (Viji et al., 2015; Ikape, 2017). Fishing gear and methods employed determine the time interval between capture and death and fish damage, which influences enzymatic reactions and

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microbial contamination (Amos et al., 2007). High ambient temperatures accelerate fish spoilage by increasing the activities of bacteria, enzymes, and chemical oxidation of fat in fish flesh (Ghaly et al., 2010). In tropical environments, fish spoil within 12 h of harvest (Ghaly et al., 2010; Akintola and Fakoya, 2017). Spoilage reduces the quality of fish, resulting in low market prices (Akande and Diei-Ouadi, 2010).

Tanzania is surrounded by rich marine resources from the Indian Ocean, and a large portion of the population relies on these marine resources (Jiddawi and Öhman, 2002; Hamidu, 2014). The fisheries sector in Tanzania is dominated by small-scale fishers that produce 95% of the total marine catch (Hamidu, 2014). The majority of SSF occur in rural areas with limited access to basic fishing tools and services (Jiddawi and Öhman, 2002). The SSF is constrained by inadequate infrastructure, including a lack of capacity for processing, and poor storage and transportation facilities (Breuil and Grima, 2014). Small-scale fishers lack technical fishing skills and sufficient capital to invest in modern fishing methods (Hamidu, 2014). As a result, fish catches are normally handled and processed in poor environments, resulting in microbial contamination and spoilage. Post-harvest losses are estimated to be around 20% of the total fish weight harvested per year due to poor storage, processing, and marketing facilities (Breuil and Grima, 2014).

The small-scale marine fisheries of Tanzania comprise the majority of the coastal populations whose survival is entirely dependent on coastal fishery resources (Temple et al., 2018; Techera, 2020). Fishers operate in shallow waters within the continental shelf extending to approximately 4 km offshore using traditional fishing vessels such as dhows, canoes, outrigger canoes, and dinghies (Jiddawi and Öhman, 2002; Hamidu, 2014). Simple fishing gear such as nets, traps and hooks are used, restricting fishing to depths of 30 m (Jiddawi and Öhman, 2002; Torell et al., 2007). The mode of fishing used by fishers is normally influenced by their education, gender, age, and geographic location (culture) within the fishery (Bradford and Katikiro, 2019; Acharjee et al., 2021). Fishers with more capital items such as boats can fish in less-exploited grounds with higher resource abundance further from shore (Purcell et al., 2018, 2020). In addition, fishers with more years of experience in fishing resources have acquired skills and better knowledge about fishing grounds, which may increase their catch rates (Purcell et al., 2020). Males are the main actors in capture fisheries, while females are restricted to nearshore fisheries and post-harvest activities such as processing and marketing (Kleiber et al., 2015; Bradford and Katikiro, 2019). In some cases, females are excluded from certain fishing grounds, resulting in smaller catches (Hauzer et al., 2013).

Poor fishing technology normally leads to low harvests, spoilage and destruction of fish breeding patterns and sites (Torell et al., 2007; Acharjee et al., 2021). The lack of cold storage facilities and inappropriate processing skills increase nutritional and quality loss in fish (Akintola and Fakoya, 2017; Tesfay and Teferi, 2017). Quick selling of catches reduces the loss incurred by fishers because they pass on any of their losses to traders (Kaminski et al., 2020). Various coping strategies are used by fishers with varying degrees of success, but nutritional losses and spoilage still occur (Ahmed, 2008; Akande and Diei-Ouadi, 2010). Education, training, better transportation and infrastructure facilities are significant factors in reducing post-harvest fish spoilage (Acharjee et al., 2021).

Despite the crucial role of the SSF in poverty reduction and food security (Béné et al., 2007), few studies have addressed the constraints and needs of the SSF in Tanzania. Therefore, this study investigated factors that influence catch rates and fish spoilage in small-scale marine fisheries in the Bagamoyo District, Tanzania. The catch rates and spoilage of fish were expected to vary with: (1) the time spent fishing and selling the captured fish; (2) age and sex of the fisher; (3) education level of the fisher; (4) fishing experience; (5) fishing vessels and gear used; and (6) infrastructure and preservation of catches.

2. Materials and methods

2.1. Study area

Bagamoyo district is located between 37° and 39° east, and between 6° and 7° south of the equator, approximately 65 km from Dar es Salaam. The district has a coast line of 100 km, which is characterised by sandy or muddy tidal flats, mangroves, coral reefs, seagrass beds, seaweed, and lagoons (Jiddawi and Öhman, 2002; Silas et al., 2020). These ecosystems play a major role in supporting local people, providing a source of food and cash (Torell et al., 2007; Silas et al., 2020). There are nine coastal fishing villages in the Bagamoyo district (Mkama et al., 2010). Small-scale fishing is the most important economic activity for the people in these villages, where about 70–80% of the people are, to some extent, involved in fishing activities (Torell et al., 2007; Mkama et al., 2010; Silas et al., 2020). Most small-scale fishers in the district obtain fish in shallow water habitats and near reef areas in the vicinity of the coastline (Mkama et al., 2013). Other livelihood activities include boat building, salt making, charcoal making, mangrove pole cutting, seaweed farming, wage labour, and livestock (Torell et al., 2007).

2.2. Data collection

Data collection was conducted via structured interviews in May 2021. The Mlingotini fishing village, which is located along Mbegani Bay (Figure 1), was selected for this study because it has approximately 500 registered fishers, which is the highest number among the fishing villages. Additionally, the village is located close to the Mbegani Fisheries Development Centre, which was established to provide fishing education to neighbouring villages. We visited the local fisheries office, and the purpose of the research was clearly explained to the leaders. Then, the leaders called a meeting with the fishers, where we also explained the objectives of the study and the rights of the respondents during the study. A systematic random sampling procedure was used to select 40 fishers from the list of small-scale fishers operating in the village. This sample is equivalent to 8% of all fishers in the village, and it included only those who were willing to take part in the study. The study intended to interview 80 fishers, but other fishers were not willing to take part in the study. Structured questionnaires were administered to the selected fishers. Each fisher was interviewed privately and in relaxed settings, such as sitting under a tree or in another peaceful location. The survey adhered to confidentiality and informed consent from the participants. The questionnaires gathered information about the amount (kg) of fish captured per fishing session, the length of fishing sessions, the time taken to sell all captured fish per fishing session, and the amount (kg) of fish spoiled per fishing session. Additionally, the questionnaire gathered information about fish storage during and after fishing, fishing gear used, and fish processing. Socio-demographic information was collected, including age and sex of the fisher, education level, fishing experience (years), and whether the fisher had attended any formal training related to fishing. Ethical clearance for conducting the study with reference number MA.84/261/02 was obtained from the University of Dodoma.

2.3. Data analysis

We used descriptive statistics in excel to summarise demographic aspects of the respondents, fish species with the highest levels of spoilage, seasons with the highest levels of spoilage, and the opinions of the respondents regarding strategies for reducing fish spoilage.

The proportion of fish spoilage per respondent was calculated as a ratio of the amount of fish spoiled and the amount of fish captured per fishing session. This proportion and the amount of fish captured per fishing session were used as response variables. The response variables

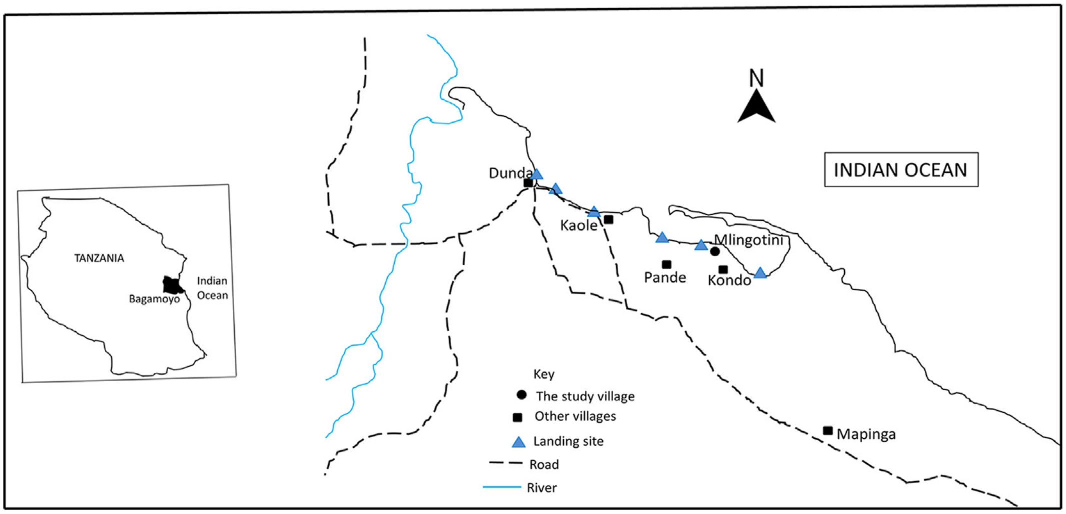

Figure 1. The location of the study village (circle) and fish landing sites.

were checked to determine if they conformed to the assumption of normality by using a Q-Q plot (Zuur et al., 2009). The amount of fish captured per fishing session was not normally distributed, so the Generalised Linear Model with Poisson distribution was used to evaluate factors that determine the amount of fish captured per fishing session. One of the assumptions of the Poisson distribution is that the mean equals the variance (Zuur et al., 2009). Over-or under-dispersion happens when the variance is larger or smaller than the mean, affecting the interpretation of the model. Thus, the evaluation of the model was done using the dispersion parameter, i.e., the ratio of residual deviance and the degree of freedom. The dispersion parameter was 1.5, indicating that the model conforms to the assumption of equal variance (Zuur et al., 2009). We ran a multivariate model with all independent variables, including fishing experience, length of fishing sessions, time used to sell the fish captured, age and sex of the fisher, education level of the fisher, and whether the fisher had attended any formal training related to fishing.

Beta regression was used to examine the factors influencing fish spoilage. Beta regression is a flexible method for modelling continuous random variables that assume values between 0 and 1, such as rates, proportions and percentages (Ferrari and Cribari-Neto, 2004; Espinheira et al., 2008). We fitted a full beta regression model using fishing experience, length of fishing sessions, time used to sell the fish captured, age and sex of the fisher, education level of the fisher, fishing gear (hooks, nets), and whether the fisher had attended formal training related to fishing as independent variables.

Multicollinearity between the independent variables was checked using a variance inflation factor (VIF), which ranged between 1 and 3.5, indicating that there was no significant multicollinearity between the independent variables (Zuur et al., 2009). All the analyses were done in R version 4.0.3 (R Core Team, 2020).

3. Results

3.1. Social-demographic characteristics of the Fishers

A total of 40 small-scale fishers were interviewed, of which 28 were males and 12 were females, who mainly targeted invertebrates from nearshore habitats. The age of the fishers ranged from 20 to 55 years, where 30 fishers were aged between 20 and 30 years, six aged between 31 and 40 years, and four aged more than 40 years. Eight fishers have completed college education, 18 have completed secondary education and 14 have completed primary education. There was no association between the level of education and the age of the fisher ($F_{2,37} = 1.6$, $p = 0.222$). Additionally, 12 fishers had received formal training related to fishing and fish handling, while 28 fishers had never received formal training. The fishing experiences of the respondents were as follows: 20 fishers have been fishing for less than 5 years, nine for 5–10 years and three for more than 10 years. The distribution showed that less experienced fishers dominate the SSF in the village. The fishing experience correlated positively with the age of the fisher ($r = 0.64$, d.f. = 38, $p < 0.001$), and the fishers with primary education had the longest fishing experience.

3.2. Fish catch and storage

The fishing sessions took an average of 11 h ± 4 SD. The interviewed fishers stored their fish in containers filled with ice blocks or in buckets filled with cold water during the fishing sessions. The amount of fish captured (mean ± SD) per fishing session was 18.5 kg ± 3.8. The amount differed with the experience of the fisher, age of the fisher, education level of the fisher and time spent selling the captured fish (Table 1). The

Table 1. The Poisson regression model estimates for the factors that influenced the amount of fish captured (kg) per fishing session.

Response variable	Explanatory variable	Coefficient	St. error	z-value	p-value
The amount of fish captured per session (kg)	Intercept	10.066	1.763	5.710	<0.001
	Fishing experience (yrs)	0.050	0.019	2.650	0.008
	Age of the respondent	-0.070	0.017	-4.015	<0.001
	Length of the fishing session (h)	-0.005	0.012	-0.420	0.674
	Received fishing training (yes/no)	0.093	0.182	0.515	0.606
	Time taken to sell the fish (h)	-0.024	0.006	-3.899	<0.001
	Primary education	0.776	0.202	3.837	0.001
	Secondary education	0.556	0.207	2.678	0.007
	Male fishers	-1.076	0.441	-2.435	0.014
	Age *male fishers	0.039	0.016	2.455	0.014

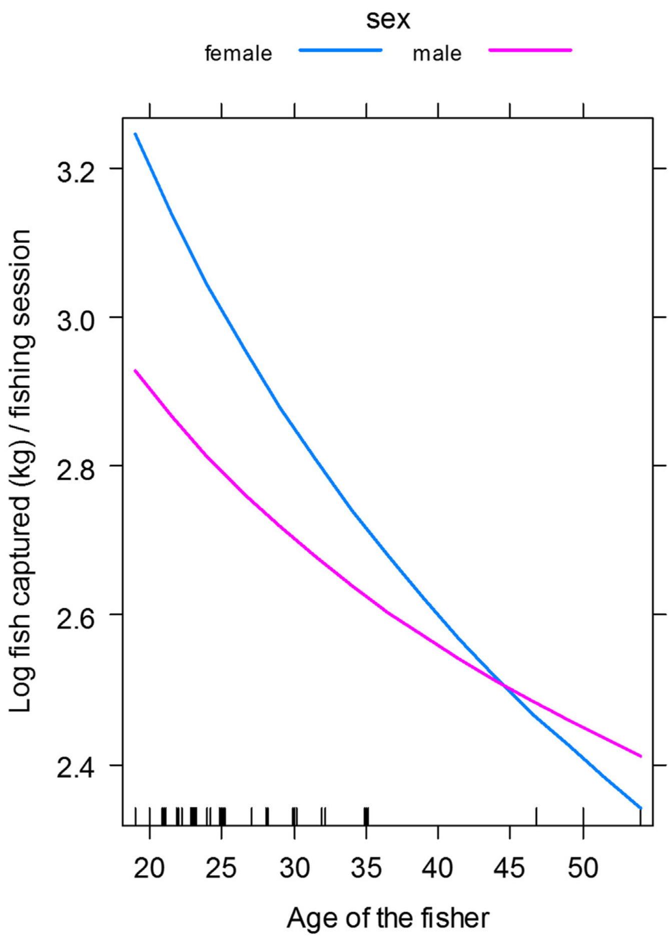

Figure 2. The relationship between fish catch per fishing session and the age of the fisher. The catches decreased with age in both male and female fishers, but the level of change was higher in females than in male fishers.

fish catch increased with the fishing experience of the fisher and decreased with the age of the fisher (Table 1). The effect of age on the amount of fish captured per fishing session was higher in female than in male fishers (Figure 2). Additionally, the amount of fish caught per fishing session was lowest in fishers with a college education compared to those with primary and secondary education (Figure 3).

3.3. Fish spoilage

The level of spoilage differed between the fish species. About 46.7% of the fishers interviewed mentioned *Lutjanus* spp. as the species with the highest level of spoilage (Table 2). Most of the fish spoilage happens during the hot seasons (Table 2). On average, 10% ± 2.3 SD of the total weight of the captured fish per fishing session spoils. The level of spoilage decreased with the fishing experience of the fisher and increased with the age of the fisher (Table 3). The effect of a fisher's age on fish spoilage was higher in male fishers than in female fishers (Figure 4). Fishers without formal training related to fishing reported higher spoilage compared to the fishers who had attended training (Figure 5a). Furthermore, spoilage was lower in fishers with primary education than in those with secondary and college education (Figure 5b). Poor storage facilities were highlighted by the fishers as the main cause of fish spoilage (Table 2). Thirty-five fishers said they store the fish in boxes filled with ice blocks during fishing, while five said they store the fish in buckets filled with cold water. After fishing, the fishers use sun-drying, frying, or smoking as methods to reduce spoilage before selling their fish.

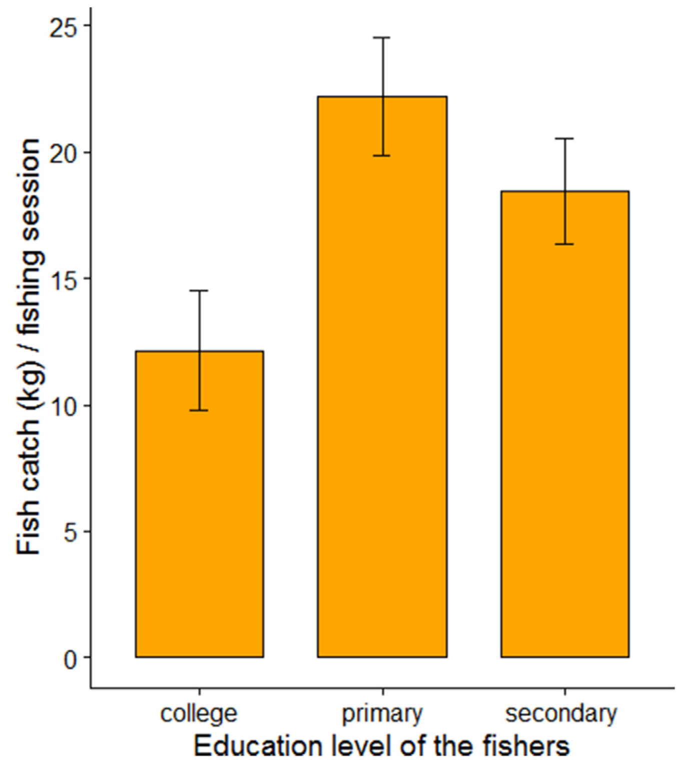

Figure 3. The amount of fish caught per fishing session by fishers with primary, secondary and college education. Error bars represent the standard deviation of the mean.

4. Discussion

The study shows that fishing sessions take an average of 11 h and a fisher catches an average of 18 kg of fish per session. The majority of the fishers were young people aged 20–30 years old who had been fishing for less than 5 years. About 10% of the total weight of captured fish is lost through spoilage. Some fish species spoil quicker than others, perhaps due to variations in nutrient content and body size. Most of the spoilage happens during the hot season. Attributes of the fisher, such as fishing experience, age and sex, education level and training determine fish capture and spoilage. Long fishing sessions do not increase fish catches, but result in more spoilage of fish.

4.1. Determinants of fish catch

The quantity of fish captured per fishing session increased with the fishing experience of the fisher. However, the majority of the fishers have been fishing for less than 5 years, showing that the village is dominated by less experienced fishers. In other parts of the world, the SSF is dominated by highly experienced fishers (Marín-Monroy, 2016; Macusi et al., 2021). Fishing experience is an important human capital in the SSF industry (Sesabo and Tol, 2007). Experienced fishers have more skills and knowledge about fishing grounds, fishing gear and vessels, seasonal variations in fish availability and water currents, which increase fishing efficiency (Sesabo and Tol, 2007; Purcell et al., 2020). The importance of fishing experience on the catch rate has been reported elsewhere in the fishing sector (Tingley et al., 2005; Alom et al., 2020; Macusi et al., 2021). Surprisingly, the fishers with primary education reported more catch per fishing session compared to fishers with college education. The fishers with primary education had been fishing for a longer time, meaning that they had acquired more directly relevant knowledge. Additionally, fishers with low or no education tend to spend more time fishing, thus increasing their catch (Ahmed, 2008). Here, a fisher with

Table 2. The variation in spoilage between fish species and seasons; the causes of fish spoilage and measures used by the fishers to reduce the spoilage.

Questions	Response	Number of the respondents
Which fish species spoils more rapidly?	*Lutjanus* spp	18
	Trachinotus africanus	12
	Oreochromis niloticus	5
	Lethrinus rubrioperculatus	5
Which season has the highest spoilage?	Hot seasons	34
	Hot and rainy seasons	5
	All seasons	1
What are the causes of fish spoilage?	Poor storage facilities	10
	Lack of education on fish processing	9
	Poor fishing tools	7
	Poor transport	6
	Delayed marketing	6
	Unavailability of loans	2
Preservation methods to reduce spoilage	Use of ice blocks	13
	Sun drying	11
	Frying	10
	Smoking	6

primary education reported a fishing session of 15.4 h compared to 8 h for fishers with secondary education and 9 h for fishers with college education. High levels of education tend to discourage people from participating actively in SSF (Inoni and Oyaide, 2007). Related studies in Mexico (Marín-Monroy, 2016) and in the Amazon (Keppeler et al., 2020) found that more educated fishers spend less time fishing and see fishing as an alternative income-creating activity. In southeast Asia, Pollnac et al. (2001) found that more educated fishers are likely to leave the fishery if alternative activities are available.

The fishers who had received formal training related to fishing reported more catch per fishing session compared to fishers without formal training. Fishers with access to extension services and training are well informed about the process of fishing and fish handling. Training helps fishers to be aware of their limitations and learn skills that make them more effective at fishing (Purcell et al., 2018; Yanfika et al., 2019). In addition, trained fishers have knowledge and access to loans, which are important for buying fishing tools and other inputs (Abiodun, 2021). However, the number of fishers who received formal training was small (31%), suggesting that more efforts are needed to increase training of small-scale fishers. Fishers without formal training depend on skills learnt from relatives and fellow fishers.

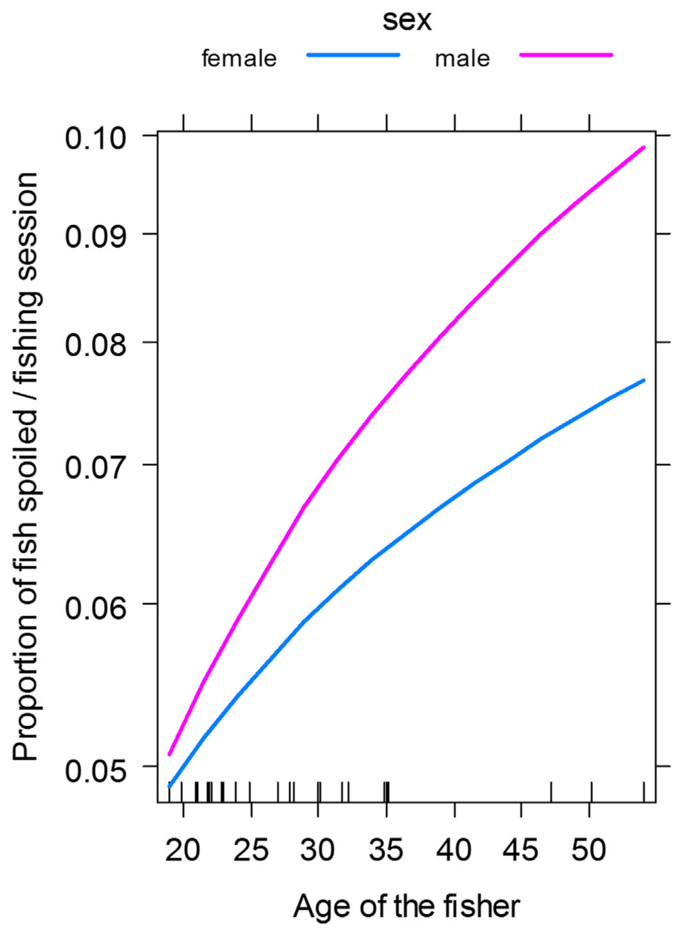

Figure 4. The relationship between the proportion of fish spoiled per fishing session and the age of the fisher. The spoilage increased with age in both male and female fishers, but the level of change was higher in the male than in the female fishers.

The amount of fish captured did not vary with the length of the fishing session. The catch rates are expected to increase with fishing effort, which is determined by the fishing tools used and the amount of time spent fishing. Poor fishing technology tends to increase the time spent fishing and prevent fishers from reaching good fishing grounds (Jiddawi and Öhman, 2002; Hamidu, 2014). According to Sesabo and Tol (2007), catch per unit time is a good indicator of fish stock abundance. Artisan fish catches in coastal areas of Tanzania have declined significantly over the last decade (Silas et al., 2020). Thus, an increase in fishing time does not necessarily increase catch when stock abundance is low (Hamidu, 2014; Keppeler et al., 2020). Fish stocks and catch rates

Table 3. Beta regression estimates of the factors influencing fish spoilage (proportion of the captured fish (kg) that spoils).

Response variable	Explanatory variable	Coefficient	St. error	z-value	p-value
The proportion of fish spoiled per fishing session	Intercept	-21.812	5.671	-3.846	$<$0.001
	Fishing experience (yrs)	-0.256	0.074	-3.435	$<$0.001
	Age of the fisherman	6.238	1.935	3.223	0.001
	Length of the fishing session (hrs)	0.095	0.016	2.620	0.008
	Received fishing training (yes/no)	-1.638	0.532	-3.079	0.002
	Time taken to sell the fish (hrs)	-0.179	0.265	-0.676	0.498
	Fishing gear: hooks	0.547	0.267	2.045	0.041
	Primary	-0.978	0.593	-1.650	0.098
	Secondary education	-0.339	0.612	-0.555	0.579
	Male fishers	12.528	5.743	2.181	0.029
	Age* male fishers	-3.922	1.776	-2.208	0.027

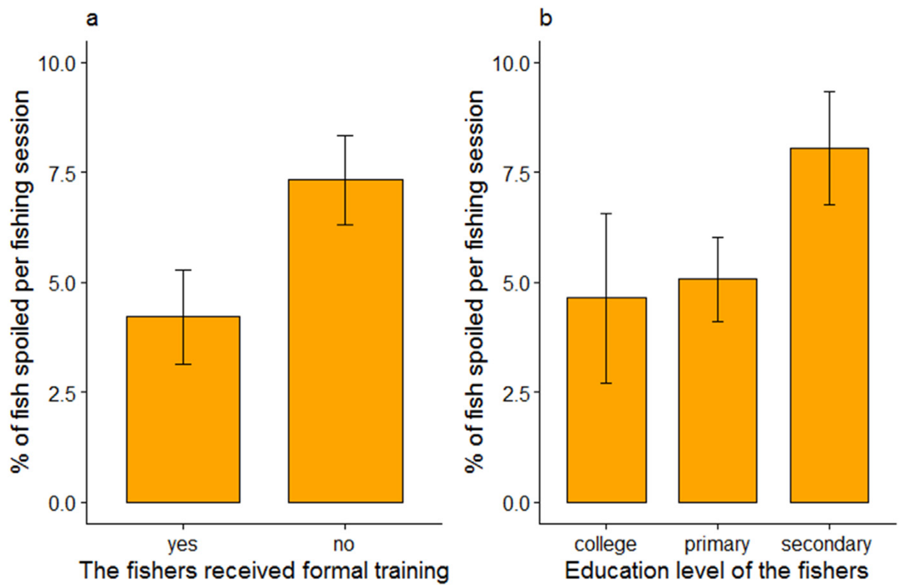

Figure 5. Differences in the proportion of fish spoiled between (a) fishers with and without formal fishing training (b) fishers with primary, secondary and college education. Error bars represent the standard deviation of the mean.

continue to decline in different parts of the world (Pomeroy, 2012; Muallil et al., 2014; Macusi et al., 2021). In the Amazon region, fishers practise group fishing to increase the catch rate (Keppeler et al., 2020).

Most of the fishers were young adults aged 20–30 years, which suggests that the fishing sector has enough young people who are needed in this industry. The age structure of the fishers is comparable to that reported by Silas et al. (2020) from extended coastal areas of Tanzania and by Assefa et al. (2018) in Ethiopia. Related studies in the Philippines reported older fishers (Muallil et al., 2014; Macusi et al., 2021). The young fishers tended to catch more fish per fishing session compared with the older fishers. The effect of age on the amount of fish caught was higher in female fishers than in male fishers. Motivations, aspirations and perceptions of fishing activities differ between young and old people and between men and women (Bradford and Katikiro, 2019). The fishing experience and the age of the fisher correlated positively, showing that the older fishers have been fishing for a longer time. However, despite this positive relationship between age and experience, the catch rates decreased with the age of the fisher. This is because small-scale fishing is a labour-intensive activity that requires strong and healthy people (Macusi et al., 2021). Young men and women are physically strong and efficient, thus they invest more energy in acquiring enough money to establish their own families. Additionally, young and middle-aged fishers are more willing to adopt new technologies than older fishers (Wagenaar and D'Haese, 2007). Age also determines tolerance to harsh weather, and the oldest fishers are more vulnerable (Macusi et al., 2021). Household duties tend to restrict the time and mobility of women involved in fishing (Bradford and Katikiro, 2019). The family roles of women increase with age when they have more children and grandchildren to look after. Men normally have more time to spend fishing and looking for marketing opportunities (Fröcklin et al., 2014; Bradford and Katikiro, 2019).

4.2. Determinants of fish spoilage

The fishers reported higher spoilage during the hot season, which agrees with a study by Mavuru et al. (2022) in Zimbabwe. Bagamoyo district is warm, with an average annual temperature of about 26.6 °C (Mwanga et al., 2019). In hot months, temperatures can reach 32 °C (Lyimo et al., 2013), increasing the risk of fish spoilage. The spoilage process of fish starts within 12 h of their catch (Berkel, 2004). High ambient temperatures such as 20 °C and above create favourable conditions for fish spoilage by increasing lipid oxidation and microbial activity (Ghaly et al., 2010; Adelaja et al., 2018). In some regions, the spoilage tends to be higher during the rainy season because drying fish is extremely difficult during this season (Akande and Diei-Ouadi, 2010; Assefa et al., 2018).

The extent of spoilage differed between the fish species, probably due to differences in nutritional composition and body size between fish species (Akintola et al., 2022). *Lutjanus spp* and *Trachinotus africanus* were identified as the species with the highest spoilage. These fish species have high levels of nutrient content and moisture, making them more perishable (Gao et al., 2014). Furthermore, differences in spoilage between species are caused by the type of gear used and the length of the fishing session. Some gear types target specific fish species, thus the extent of spoilage may vary between species depending on the type of gear used (Humphries et al., 2019; Quijano et al., 2021). In addition, some gear damages fish tissue, thus increasing microbial contamination (Akande and Diei-Ouadi, 2010; Alam et al., 2021). The fishers who used hooks reported a higher proportion of spoilage. However, there was no correlation between the use of hooks and the species with higher spoilage. Setting gear for a long time increases spoilage (Akande and Diei-Ouadi, 2010; Alam et al., 2021), and the fishing duration may vary between fish species depending on the availability. Other factors such as climate change have modified the distribution and productivity of fish species (Muringai et al., 2020; Silas et al., 2020). As a result, fishers have changed fishing grounds from near shore to further offshore, which increases fishing time and spoilage risks (Silas et al., 2020; Macusi et al., 2021).

Fishers who received formal fishing training and those with long fishing experience reported smaller proportions of spoilage. Fishers who have been working for a long time in the fisheries sector have acquired skills through work. The skills enable them to handle fish properly to reduce bacterial contamination and other losses (Adelaja et al., 2018). Additionally, experienced fishers are more informed about marketing and potential buyers, thus selling their catch in a short time. The findings of this study are in agreement with related studies in Nigeria (Adelaja et al., 2018) and Bangladesh (Acharjee et al., 2021). Training improves access to credit and value-addition initiatives (Akanni, 2010). The SSF in most developing countries is dominated by people who are illiterate or have a low education level (Trina et al., 2016). Thus, learning through experience is an important component of the SSF in developing countries (Ikoja-Odongo and Ocholla, 2003).

The fishers with secondary education reported higher levels of spoilage compared to those with primary and college education. This group of fishers also reported longer selling times of their catch (12.9 h) compared to 11.7 h for the fishers with college education and 10.8 h for the fishers with primary education. Education reduces post-harvest fish losses in Ghana (Gyan et al., 2020) and Bangladesh (Acharjee et al., 2021). Educated people are eager to learn and adopt good practises for handling fish to reduce losses (Adelaja et al., 2018). However, the fishers with primary education in this study reported lower levels of spoilage. As stated earlier, these fishers have more fishing experience and thus are aware of the best fish handling practises and marketing strategies that reduce spoilage. There is no effective marketing agency in the fishing villages in Tanzania; thus, fish mongers and traders visit different landing sites daily to buy fish and transport them to markets in major towns (Hamidu, 2014). This marketing system is practised in most other developing countries in Africa and Asia (Akintola et al., 2022).

The spoilage of fish increased with the age of the fishers and was more marked in male than female fishers. Young people are more flexible and aware of technology, thus they get information about fishing and fish handling and may invest more time in handling fish to reduce spoilage. For example, Adesoji and Kerere (2013) found that young fishers in Nigeria have more knowledge than older fishers, which contributed to fewer post-harvest losses. However, a study by Adelaja et al. (2018) found that the level of spoilage decreased with the age of the fisher. The authors emphasised that as fishers age, they gain more knowledge and skills for dealing with post-harvest losses. However, as a fisher's age increases beyond a certain level, their experience may not matter as they lack the energy required for active engagement in fishing activities and proper handling of the fish (Appiah et al., 2020).

The extent of post-harvest fish loss affects men and women differently (Kaminski et al., 2020; Kruijssen et al., 2020). Female fishers, especially the older ones, are involved in the collection of invertebrates, nearshore fishing and processing activities such as frying, drying and smoking, which reduce spoilage. The females reported shorter selling times for their catch than the males (10.1 vs. 13, hrs respectively), reducing the spoilage. Additionally, larger species of fish spoil easily and take longer to process compared to the invertebrates collected by females (Kaminski et al., 2020). However, related studies have reported more physical losses in females than in male fishers (Kaminski et al., 2020; Kruijssen et al., 2020), because females rely on the labour of males to operate fishing vessels or carry heavy consignments. However, fishing near shore and gleaning for invertebrates do not require labour from males, providing females more control of their fishing activities.

The level of spoilage increased with the length of fishing sessions. The long duration of the fishing cycle causes spoilage losses, especially when cold storage facilities are not available. Long fishing sessions are normally caused by poor fishing equipment and low fish stocks (Jiddawi and Öhman, 2002). Setting gears for long hours before hauling causes high spoilage and quality loss (Tesfay and Teferi, 2017). Poor storage facilities were highlighted as a major cause of the spoilage. Many small-scale fishers use ice blocks to prevent spoilage before they secure a buyer. However, the lack of electricity reduces the availability of the ice blocks in close proximity. The lack of cold storage facilities is a critical challenge to the SSF in developing countries of Africa, South East Asia and South America (Akintola et al., 2022).

5. Conclusions and recommendations

This study shows that the social-demographic features of the fishers determine fish catch and fish spoilage. Formal fishing training increases catches and decreases spoilage. Many fishers do not have access to formal training and thus depend on skills acquired through experience. Fishers with long fishing experience reported higher catches and lower spoilage rates compared to those with less fishing experience. Long fishing sessions do not increase the amount of fish caught, but increase spoilage. Older fishers experience lower catch and higher spoilage compared to young fishers. Poor storage facilities and transport, lack of education and poor tools are the main challenges facing the SSF. Provision of training related to fish processing and handling and improvement of cold storage and transport facilities are recommended to reduce fish spoilage.

6. Limitations of the study

A lack of survey participants resulted in a smaller sample size than desired, which might have influenced the interpretations of the findings. Therefore, we intend the results of this study to serve as a baseline for expanded studies involving additional fishing villages and increased survey participants, with the aim of future interventions and policy reforms.

Declarations

Author contribution statement

Rosemary Peter Mramba: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kelvin Emmanuel Mkude: Conceived and designed the experiments; Performed the experiments;

Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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