A preliminary assessment of the post-harvest fish losses along selected fish supply chains in Kwale County, Kenya

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Abstract

Artisanal marine fisheries play a critical role in enhancing food security and supporting the livelihoods of Coastal communities in Kenya. The sustainable exploitation of this resource is however threatened by post-harvest fish losses (PHFLs) occurring along the entire fish value chain. We conducted an assessment of the PHFLs at five landing sites in Kwale County to investigate the status of these losses along selected fish supply chains in the County. The Informal Fish Loss Assessment Method (IFLAM) and Questionnaire Loss Assessment Method (QLAM) were used to collect data from key informants and value chain actors operating at the landing sites. Sixty-five percent of the respondents reported having experienced PHFLs with the highest scale of loss at 34% and 15% being reported in Mkunguni and Jimbo landing sites, respectively. The fishing and marketing nodes of the fish value chains represented points at which the highest losses were encountered at 28% and 17%, respectively. The inadequacy of preservation infrastructure at the landing sites and the lack of preservation during fishing were the main factors contributing to the PHFLs. Provision of cold chain facilities, adequate drying racks and capacity building on fish handling are recommended as priority interventions to reduce the PHFLs.

Keywords: fish preservation, mitigation, fish spoilage, coast, artisanal fisheries

Introduction

Fisheries exploitation contributes significantly towards food and nutritional security, revenue generation and poverty alleviation (Mavuru *et al.*, 2022). Artisanal fisherfolk and local coastal communities rely heavily on fisheries for food provision and livelihood support (Purcell and Pomeroy, 2015). Globally, artisanal fisheries directly support 60 million livelihoods and contribute approximately 50% of fish consumed in developing countries (Tilley *et al.*, 2021). Small-scale marine fisheries in Kenya directly support above 60,000 coastal households and account for 6% of the coastal economy (Nyawade *et al.*, 2021). The sustainable exploitation of artisanal fisheries, therefore, has the potential to contribute towards socioeconomic stability through the provision of food for subsistence and income generation (Kimani *et al.*, 2018).

Fish is a highly nutritious source of animal protein, vitamins, fatty acids and minerals (FAO, 2020); and thus represents an affordable source of nutrition for low-income communities (Adewolu and Adoti, 2010). Fish is, however, a highly perishable commodity, prone to rapid spoilage induced by post-moterm microbial and biochemical activity which results in post-harvest fish losses (PHFLs) (Akande and Diei-Ouadi, 2010;

Ikape and Cheikyula, 2017). The Food and Agriculture Organization of the United Nations (FAO) defines PHFL as fish that is either discarded or sold at a relatively low price because of quality deterioration or owing to market dynamics (Wood, 1984). Morrissey (1988) defines the term post-harvest as the period of time from when a fish is separated from its growth medium; including the time a fish enters a net, is caught on a hook or in a trap. There are three main means of PHFLs, i.e., physical, quality and market force loss. Physical losses refer to fish which is discarded or eaten by insects while quality losses occur due to microbial/ biochemical/ structural changes which result in the reduction of the market value of the fish. Market force loss is caused by changes in supply and demand dynamics resulting in fish fetching a low revenue despite being of good quality (Ward and Jeffries, 2000).

The inherent high perishability of fish relegates the fisheries industry to comparatively higher post-harvest food losses which are generally estimated at 14% globally across all agricultural sectors (Tesfay and Teferi, 2017). It is estimated that artisanal fisherfolk in low and middle-income countries experience PHFLs of approximately 40% owing to poor fish handling practices and limited preservation infrastructure along the fish value chains (Prodhan *et al.*, 2022). Owing to its high perishability, preservation of the fish is imperative immediately after catch to limit microbial growth and slow down enzymatic activities which are the main drivers of fish spoilage. Temperature control is one of the most effective preservation ways to retard the spoilage of fresh fish throughout the value chain (Tesfay and Teferi, 2017).

Accurate quantification of PHFLs occurring along the artisanal fish value chain (fishing, processing, distribution and sale) is crucial to enhance accurate identification of the main factors contributing to the losses and inform the development of suitable mitigation measures (Ward and Jeffries, 2000). The dispersed nature of artisanal fisheries and the dynamic nature of the fish value chain necessitate the combination of different methods to assess all factors contributing to the three types of losses encountered. This study focuses on the determination of the scale of postharvest losses encountered in Kwale County, based on a case study conducted at 5 landing sites i.e., Jasini, Jimbo, Shimoni, Mkunguni, and Gazi. The assessment was implemented based on two methods as proposed by FAO i.e., Informal Fish Loss Assessment Method (IFLAM) and Questionnaire Loss Assessment Method (QLAM) (Diei-Ouadi and Mgawe, 2011). The IFLAM is an informal method based on participatory rural appraisal (PRA) principles while QLAM relies on interviewing a population sample in a community or geographical area using a questionnaire to validate data generated by the IFLAM. The objective of the study was to conduct a preliminary quantification of the postharvest losses across the selected fish value chains and propose suitable measures towards the reduction of these postharvest losses.

Materials and methods

Study area

The study was conducted in Kwale County, which is located in the South of the 640 km long Coast of Kenya (Kimani *et al.*, 2018). Five (5) landing sites i.e. Jasini, Jimbo, Mkunguni, Shimoni and Gazi were selected to represent the main fisheries and variations of catch volumes. Artisanal fisherfolk at Jasini and Jimbo predominantly land and process sardines while at Shimoni and Mkunguni, mixed reef fin fish dominate the catches. The catch landed at Gazi landing site constitutes a combination of both. Seasonal North East and South East Monsoon winds have a major influence on the patterns of fisheries exploitation with the former season which occurs from September to April being characterized by comparatively higher catches (Johnson *et al.*, 1982)

Study design

The study was conducted using a combination of two post-harvest loss assessment methods as recommended by FAO (Diei-Ouadi and Mgawe, 2011), with both methods relying predominantly on qualitative data collection techniques through questionnaire administration and observation.

Informal Fish Loss Assessment Method (IFLAM)

The IFLAM phase reconnaissance visits to the five (5) landing sites were conducted followed by detailed interviews using semi-structured key informant interview guides (Appendix 1) administered to key informants i.e. selected leaders of the respective Beach Management Unit (BMUs). The key informants provided information on the status of the respective landing sites in terms of gear types, catch volumes, main species landed and post-harvest dynamics including the number of value chain actors, fish handling activities, the approximate scale of post-harvest losses and measures implemented to reduce the losses. The provided information was subsequently validated through the use of pre-formulated observation guides to assess the activities conducted at the landing sites by the fish value chain actors. The main sources of post-harvest losses as well as assess the status of the infrastructure at the sites were noted.

Questionnaire Loss Assessment Method (QLAM)

Semi-structured questionnaires (Appendix 2) were designed and administered to a sample of respondents from each landing site (n = 30) to obtain detailed information on their experiences including the volume and type of fish handled, fish preservation and processing techniques and scale of post-harvest losses encountered. The selection of the respondents was based on a purposive sampling technique. Each sample contained representatives of the main actors involved in the fish value chain i.e. fishermen, fish processors and fish traders. The questions were administered to each respondent as descriptively as possible to enable the respondents to differentiate the types of losses occurring along the supply chain.

Data entry and analyses

All data from the questionnaires was converted into electronic form by entry into MS Excel spreadsheets. Open-ended responses were pre-analysed and coded based on the main themes identified. The datasets were then subjected to cleaning and harmonization. Data analysis was conducted using MS Excel and mainly involved descriptive statistics, summaries such as percentages and generation of graphical illustrations.

Results and discussion

Fishing and fish handling infrastructure based on the IFLAM

During the IFLAM phase of the survey, it was reported and observed that majority of the artisanal fishermen at the landing sites use traditional wooden fishing vessels such as dugout canoes, outrigger canoes, sailboats and dhows (Table 1), with a carrying capacity of 2 to 20 crew depending on the size of the vessel; which was largely determined by the target fishery as highlighted by Nyawade *et al.* (2021).

The key informants interviewed during the IFLAM phase reported that fisherfolk targetting reef finfish used smaller vessels while vessels used to exploit the sardine fishery and offshore fisheries were larger with outboard engines. 89% of the reported 450 fishing vessels were unmotorized; contributing significantly to long delays during transit to and from the fishing grounds. A variety of fishing gear was used at all the landing sites depending on the target fisheries. These included handlines, gill nets, reef nets, barricades, basket traps, monofilaments, seine nets and longlines and spear guns. Basket traps and ring nets were the most commonly used at the 5 landing sites (Table 1). The type of gear and fishing vessels used by artisanal fisherfolk have been reported to contribute to the significant losses encountered in small-scale fisheries in developing, tropical countries (Mavuru *et al.*, 2022; Mramba and Mkude, 2022). Infrastructural insufficiencies were observed particularly in the preservation and processing functions at the landing sites; resulting in lack of/ inefficient fish preservation (particularly icing of harvested fish) and/or use of unconventional and/or traditional processing techniques which exposed the harvest to conditions favouring rapid spoil-

Table 1. Status of key fishing and fish handling infrastructure at the selected landing sites as identified during the Informal Fish Loss Assessment Method (IFLAM) phase.

Category	Types	Landing Sites					
		Jasini	Jimbo	Shimoni	Gazi	Mkunguni	Total
Fishing Vessels	Fibre boat	0	0	18	5	3	26
	Mtumbwi	1	6	70	25	79	181
	Ngalawa	1	0	1	4	20	207
	Mashua	10	0	8	0	1	19
	Hori	0	17	0	0	0	17
	Total	**12**	**23**	**97**	**34**	**103**	**448**
	Motorized (No.)	***10***	***6***	***27***	***5***	***4***	***52***
	Motorized (%)	***83%***	***26%***	***28%***	***15%***	***4%***	***11%***
Fishing Gear	Basket traps	✓	✓	✓	✓	✓	5 landing sites
	Handlines		✓	✓	✓	✓	4 landing sites
	Longlines		✓	✓	✓		3 landing sites
	Ringnets	✓	✓	✓	✓	✓	5 landing sites
	Gillnets			✓	✓	✓	3 landing sites
	Baricades		✓	✓			2 landing sites
	Hook & stick		✓	✓	✓	✓	4 landing sites
	Reef seine		✓	✓	✓	✓	4 landing sites
	Monifilament			✓			1 landing site
	Main gear	***Ringnets B. traps***	***Ringnets B. traps***	***B. traps Gillnets***	***B. traps Ringnets***	***B. traps Hand lines***	
Infrastructure	Cooler boxes	X	NS		X	X	
	Ice (Flakes/ Blocks)	X	X	✓	X	X	
	Freezers	X	NS	✓	NW	✓	
	Ice flaking machine	X	X	NW	X	X	
	Potable water	✓	✓	✓	✓	✓	
	Raised drying racks	X	NS	X	NS	X	
	Toilets	X		✓	✓	✓	
	Status	***NS***	***NS***	***NS***	***NS***	***NS***	

Key: NS = Not Sufficient; NW = Not Working; X = Not Present; ✓ = Yes/ Present

age such as high temperatures. Similar results have been reported in studies on post-harvest fish losses occurring along fish value chains (Tesfay and Teferi, 2017; Kimani *et al.*, 2018; Keerthana *et al.*, 2022).

Value chain activities identified based on the IFLAM

A variety of activities were performed by specific value chain actors based at the landing sites i.e. fisherfolk, traders, and processors (Figure 1) were observed and explained in detail by the key informants during the IFLAM phase. From the observations made, 3 main value chains i.e. fresh, fried, and dried fish value chains were identified and scrutinized to understand the stages involved. Fishermen and fresh fish traders were mainly involved in handling the fresh fish. The UN-FAO strongly recommends the chilling of fish immediately after harvest to mitigate spoilage (Shawyer and Medina, 2003). However, in the present study, it was reported that none of the fishermen at the five landing sites preserve their catch using ice. Rather, they rely on timing their fishing activities based on experience to approximate the time that they would require to

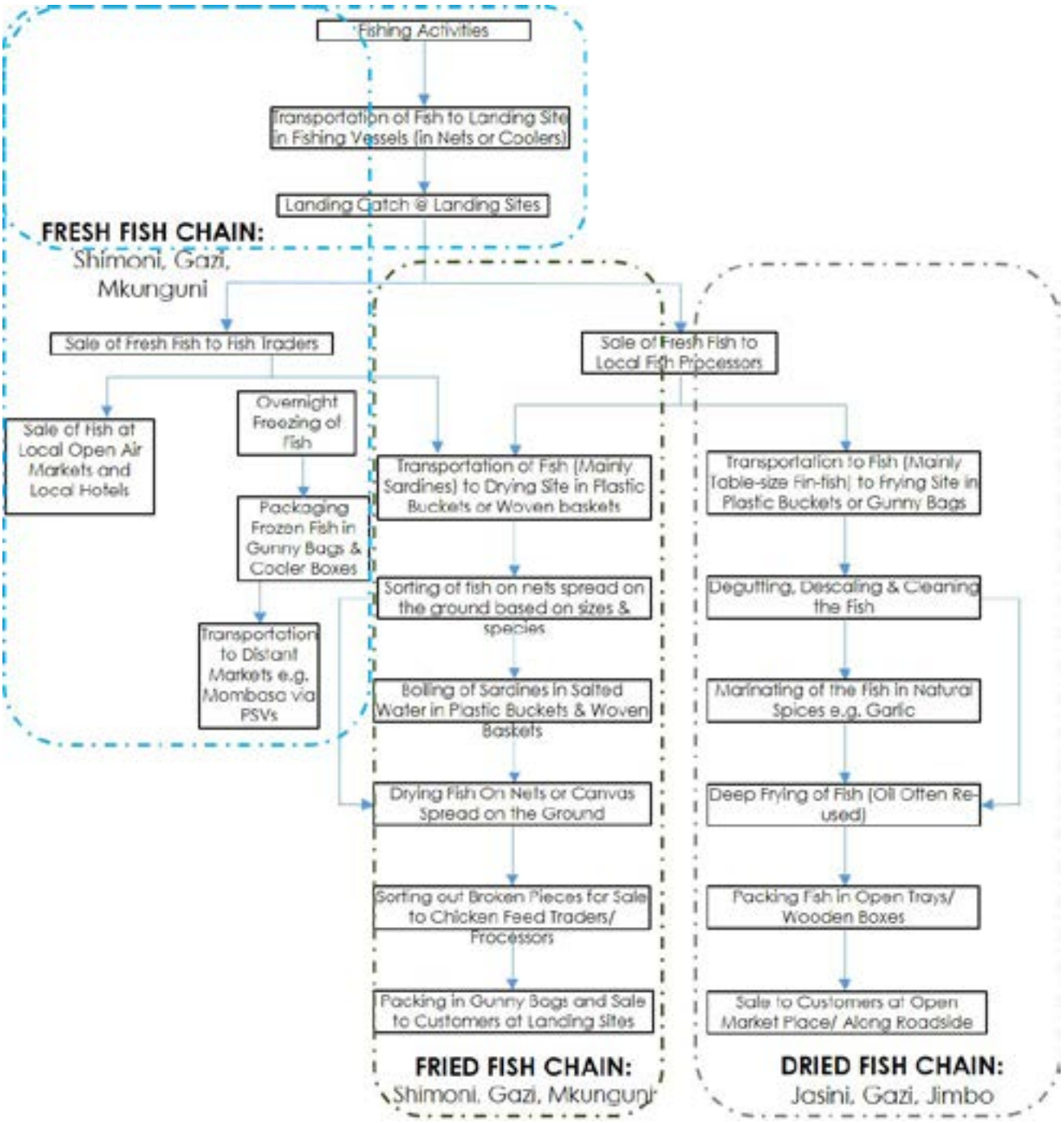

Figure 1. Flowchart of key fish handling activities at the landing sites in fresh, fried and dried fish value chains as identified during the Informal Fish Loss Assessment Method (IFLAM) phase

transport their catch to the landing site promptly and storing the fish away from direct sunlight to slow down the spoilage rates. The absence of cold-chain facilities on-board artisanal fish vessels thus contributes to the landing of fish whose quality is already compromised as reported in related studies (Kruijssen *et al.*, 2020). The fish traders use freezers and cooler boxes to preserve fish while in transit from the landing site to the market while the fish processors (drying and frying) ensured the purchase of fresh fish by assessing the quality of the landed fish. However, it was observed that they did not utilize any temperature control techniques to prevent further quality deterioration of fresh fish after purchase and during transit to the processing sites. The aforementioned findings are in line with the characteristics of most artisanal fishers in developing countries as outlined by Purcell and Pomeroy (2015).

Drivers of post-harvest losses identified based on the IFLAM and the QLAM

It was noted that the cross-cutting factors (Table 2) such as poor fish handling, insufficient fish preservation and processing infrastructure and market dynamics related to seasonal fluctuations in catch volumes were the main contributing factors towards the occurrence of significant losses at all the landing sites. Trends in the losses were driven mainly by the seasonal variations in catch volumes influenced by ocean dynamics during the NEM and SEM seasons. The former occurs between November and March and is characterized by warm temperatures light rains, calm seas and steady light winds; easing fishing activities and resulting in bumper harvests. The latter, on the other hand, takes place from April to October and is characterized by cool temperatures, long heavy rains, rough seas and strong winds (Kimani *et al.*, 2018). It was reported that the conditions during the NEM season contributed towards significant quality losses, particularly in the dried fish value chain which often requires ample solar insolation for sufficient drying to occur. These findings align with research conducted on seasonal variations in the scale of post-harvest losses in other regions (Ward and Jefries, 2000) and underscore the importance of developing climate-resilient fish value chains All the key informants were of the opinion that improvements in fish preservation/ processing infrastructure at the respective landing sites and capacity building on fish handling could have a significant impact on the reduction of post-harvest losses thereby improving the livelihoods of the value chain actors. Similar suggestions were noted in a study undertaken by Diei-Ouadi and Mgawe (2011).

Demographic profile of QLAM respondents

A total of 152 respondents drawn from the 5 landing sites were interviewed to validate the data collected during the initial two stages of the study. Fishermen represented the highest proportion of value chain actors interviewed across the board at 41% followed by fish processors (fried and dried fish) at 34% (Figure 2). This may have been influenced by the target population which was mainly fishers in the current study.

Table 2. Summary of key cross-cutting post-harvest loss dynamics identified based on feedback from interviewed fish value chain actors

Type of loss	Cause of loss	Stakeholders affected by loss	Time/season/trend of loss	Impact of loss	KIs' perception
1. Quality losses in fresh table-sized fish value chain (Shimoni, Gazi & Mkunguni)	☞ Insufficient/ Irregular supply of ice for fishermen to preserve fish during fishing and while in transit. ☞ Insufficient cold storage equipment (freezers, cooler boxes) at the landing sites	☞ Fishermen ☞ Fresh fish traders ☞ Local fish processors (i.e. Mama Karanga)	☞ All year round ☞ The losses are on the increase due to the influx of new value chain actors who are not trained on best fish handling practices	☞ Reduced income by fishermen and traders increases the poverty index ☞ Fish products unable to meet standards required for export to high-end markets	☞ Donor agencies and government agencies should frequently re-train all fish value chain actors and monitor adherence to the training skills
	☞ Poor fish handling skills (unsanitary & rough) during fishing and landing resulting in contamination of fish		☞All year round ☞ Ice-flaking machines in Shimoni gradually accrued high operational costs which BMU members were unable to meet. The machine often remains unoperational	☞ Low returns for fishermen and traders from the sale of low-quality fish ☞ High downstream losses for fried fish traders due to the short shelf life for processed products using low-quality	☞ The BMU should be supported by local and national government to meet operational costs of the ice-flaking machine ☞ Fishermen require training on the importance of using ice to preserve fish at sea

2. Quality losses in fresh sardines value chain (Jasini, Jimbo & Gazi)	☞ Lack of spacious cold storage compartments in fishing vessels	☞ Fishermen ☞ Fresh sardine traders ☞ Sardine processors	☞ All year round ☞ During bumper harvests in the NEM season, the scale of losses is even higher as the fishermen haul in tonnes of fish which remain exposed to weather elements throughout fishing and during transit	☞ Wastage of catch through discard of excess catch owing to lack of sufficient storage space in the vessel	☞ Fishermen need commercial fishing vessels provided by the Government to enable them effectively handle and store catch in all seasons
	☞ Lack of ice flaking machine at Jimbo, Jasini and Gazi landing sites for a steady supply of ice to preserve landed sardines	☞ Fishermen ☞ Fresh sardine traders	☞ All year round	☞ Rapid deterioration in the quality of unpreserved fish results in a reduction in the market price of fish forcing fishermen and traders to sell at throw-away process Production of poor-quality dried sardines	☞ Installation of ice flaking machines near the landing sites is crucial
	☞ Lack of raised racks for sorting sardines before boiling	☞ Sardine processors	☞ All year round	☞ Sardines contaminated with sand particles end up having low eating quality thus are not attractive to consumers or have to be sold at low process as fish feed ☞ Fish products unable to meet standards required for local and international high-end markets	☞ Most processors lack knowledge on available innovations to prevent sardine contamination. ☞ Creation of awareness as important as the provision of the raised racks

3. Quality losses in the dried sardines value chain (Jasini, Jimbo & Gazi)	☞ Use of plastic and woven containers to boil sardines during processing – introduced contaminants and carcinogens ☞ Broadcasting sardines on the ground for drying thus exposing them to high contamination	☞ Sardine processors	☞ All year round ☞ During the rainy/ cold season losses of sardines during processing are particularly high due to incomplete drying/ spoilage onset as a result of damp weather conditions	☞ Sardines contaminated with sand particles end up having low eating quality thus are not attractive to consumers or have to be sold at low process as fish feed ☞ High losses when spoilage of sardines occurs due to unfavourable weather	☞ The available drying racks are insufficient. Increase the number of drying racks with polythene covers to keep moisture at bay ☞ Overhaul of the processing system through introduction of food-safe boiling containers is necessary. Creation of awareness on the dangers caused by heating plastics is crucial.
4. Quality losses in the fried fin-fish value chain (Shimoni, Gazi & Mkunguni)	☞ Provision of low-quality fresh fish by fishermen and traders ☞ Lack of preservation equipment for storage of purchased fresh fish during transit and before processing ☞ Contamination of fish during storage due to exposure to contaminants such as dust and kerosene smoke/spills when selling using open display shelves	☞ Fried fish processors	☞ All year round	☞ Discard of spoilt fried fish resulting in low returns and high losses	☞ Mama Karanga require training on the identification of low-quality fresh fish, proper fish handling techniques and value addition for product diversification ☞ Provision of ample preservation equipment e.g. freezers & cooler boxes and food-safe fish display containers

5. Quantity losses in the dried fish value chain (Jasini, Jimbo & Gazi)	☞ Discards at sea during bumper harvest season due to limited space ☞ Lack of ample storage space in fishing vessels ☞ Insufficient processing equipment resulting in broadcasting of sardines on the ground when sorting and drying resulting in predation and dropping of pieces of sardines ☞ High quantity of sardine fragments after drying due to constant moving of the sardines from the ground during drying	☞ Sardine fisherfolk ☞ Sardine processors	☞All year round ☞Losses are higher during bumper harvest season and in cold weather	☞ Reduced income for fishermen due to discard of catch ☞ Unsustainable fishing practices (discarding) endangering ecosystem health ☞ Reduced volume of final products (dried sardines) due to fragmentation resulting in lower income as fragments are sold as chicken feed	☞ Provision of spacious fishing vessels ☞ Sardine processors require more processing facilities such as raised racks to avoid drying on the ground
6. Market losses in fresh fish and sardines (All sites)	☞ Insufficient infrastructure for storage and preservation particularly during bumper harvests	☞ Fishermen ☞ Fish traders	☞ During bumper harvest season when catch volumes are very high	☞ Low returns from sale of fish and fish products at throw-away prices to avoid losses. Contributes to increased poverty	☞ Value chain actors require assistance in creation and maintenance of strategic market linkages, including in the export market ☞ *Provision of bulk storage facilities to provide ample space for all at all seasons*

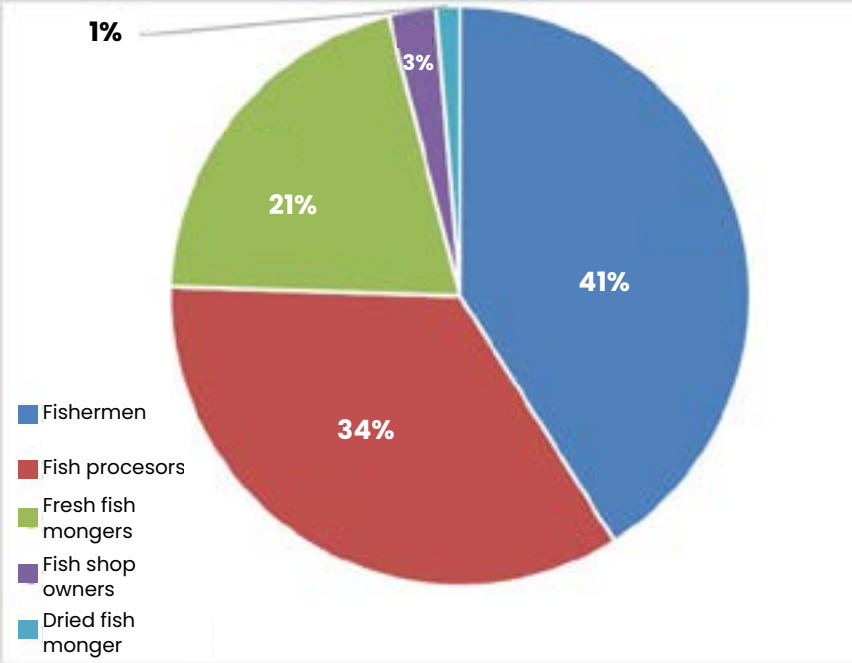

Figure 2. Occupations of respondents interviewed during the Questionnaire Loss Assessment Method (QLAM) phase.

The findings show that 70% of the 152 respondents were male and 30% female while the youth (≤35 years old) represented 23%, with 70% of the actors being engaged in fish value chain activities for 6 to 7 days a week – indicating that these activities were their main source of livelihood and are male-dominated. According to Manyungwa-Pasani *et al.* (2017), male players constitute a significantly larger proportion of fish value chain actors globally in comparison to their female counterparts. Women, however, play key roles that are essential to the sector including fish processing and repair of artisanal fishing gear such as fishing nets (Williams, 2010). Diei-Ouadi *et al.* (2014) recognized that addressing this disproportionate gender representation in fish value chains has the potential to contribute towards the reduction of post-harvest losses by amplifying the contribution of women in sustainable fisheries management.

Catch volumes and composition based on the QLAM

The value chain actors reported handling a variety of nearshore (reef) and offshore fish species. The main fish species landed and processed (drying or frying) included *Siganus spp* (*Tafi*), *Lethrinus spp* (*Changu*), *Leptoscarus spp* (*Pono*), Caranx (*Kolekole*), *Parupeneus spp* (*Mkundaji*), Tunas (*Viboma*), Kingfish (*Nguru*), Snappers and Sardines (*Kimarawali, Katashingo* and *Simsim*). The catch volumes varied at the different landing sites based on the monsoon-based seasons (NEM & SEM). Figure 8 illustrates the variation in the average seasonal catch volume reported per individual at each landing site. The seasonal bumper harvests in selected fisheries such as sardines were associated with significant losses due to limited infrastructure to preserve the massive landings. While species-specific post-harvest fish losses were not quantified in this study, research conducted in other regions indicates that the scale of losses encountered often differs with the type of fish harvested (Prodhan *et al.*, 2022). A subsequent study using the load tracking method (Ward and Jeffries, 2000) would enable the quantification of losses occurring in specific marine fisheries in Kenya.

Scale and frequency of post-harvest losses based on the QLAM

The respondents reported that spoilage of fish i.e. quality deterioration was the main type of loss that was encountered at most landing sites (Table 2); with quantity losses being reported mainly in the dried sardines value chain. Most respondents (65%) reported having encountered post-harvest losses at some point in their fish value chain activities; with a significant majority reporting loss frequencies of up to twice a month (Kimani *et al.*, 2018). The scale of the losses varied from one landing site to another (Fig. 9); with respondents at Mkunguni reporting the highest proportion of total catch lost per individual at 34%; followed by the Jimbo landing

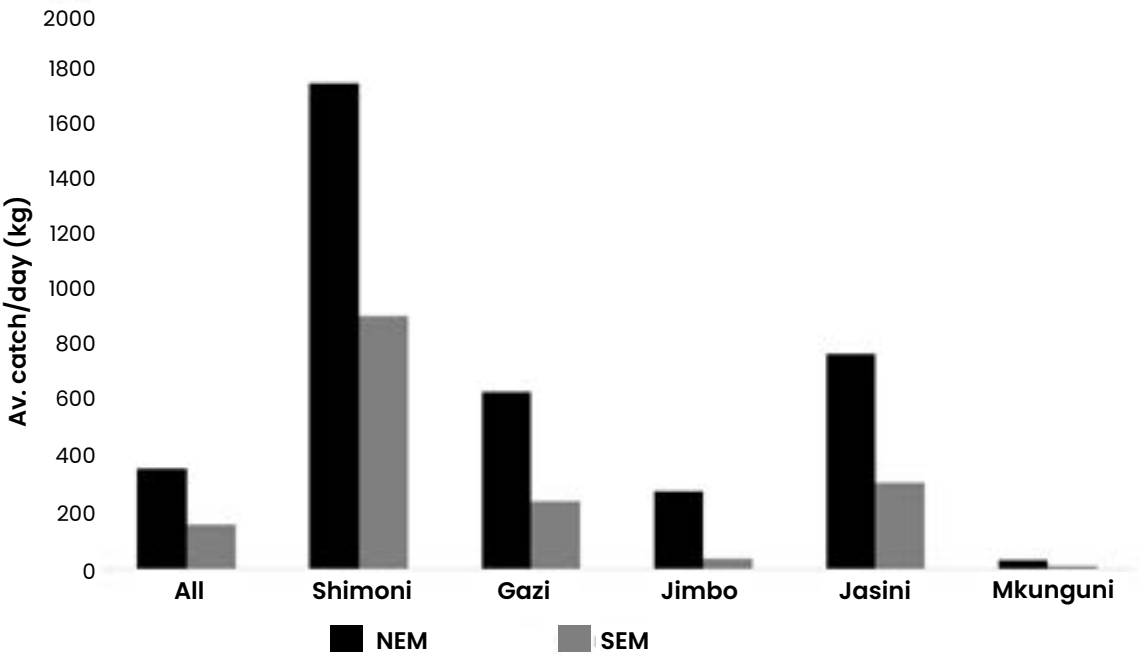

Figure 3. Seasonal fish catch volume (kg) variations at the landing sites. NEM: North East Monsoon season; SEM: South East Monsoon Season.

site at 15%. The points at which the losses occurred along the value chain were fishing (28%), at the fresh fish markets (18%) and during processing (17%). The observed variations in the post-harvest losses encountered at different landing sites were attributed to the differences in the catch compositions and preservation infrastructure present at the selected sites. This illustrates the need to develop inclusive implementation frameworks that will drive the provision of the requisite post-harvest management infrastructure along all fish value chains in Kenya as proposed by Odoli *et al.* (2019). Respondents reported that the low-quality fish is often split, heavily salted and dried into a product locally known as *ng'onda*; which fetches lower prices than fresh fish due to the moisture loss in the process of drying. While drying was reported as an innovative technique used by the respondents in this study to upcycle low-quality fish, the use of rotten fish to produce dried fish for human consumption was noted as a significant malpractice. This observation justifies the need to capacity-build the artisanal fisherfolk on the best practices in fish handling and processing to produce value-added products that are fit for human consumption (Kumolu-Johnson and Ndimele, 2011).

Factors contributing to post-harvest losses & proposed solutions

Several factors were identified as the main causes of the post-harvest losses (Table 3). Chief among these was the lack of necessary cold-chain infrastructure and equipment such as freezers, cooler boxes and ice flake-making machines, in addition to the prohibitively high cost of electricity bills accruing from cold-chain facilities connected to the national grid. This was the situation at Shimoni, Gazi and Mkunguni landing sites where modern facilities were available but frequent breakdowns led to inconsistencies in fish preservation, which contributed to significant losses – a common challenge in the fish cold chain in the tropics (Ikape and Cheikyula, 2017). Within the sardine value chain in Gazi, Jimbo and Jasini, the main cause of losses highlighted was the inadequacy of drying racks resulting in high quality and quantity sardine losses due to drying the fish on the ground. Research findings have provided evidence of the impact of improving fish drying infrastructure

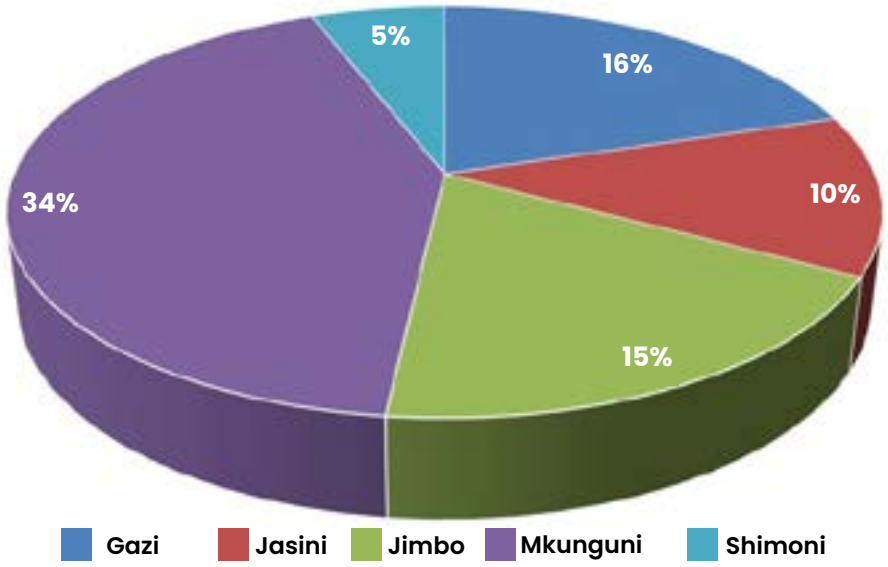

Figure 4. Proportion of total fish lost post-harvest per value chain actor at the landing sites.

on the reduction of post-harvest losses in the sardine fish value chain (Mhanga and Mwandya, 2022).

Cold chain equipment such as cooler boxes, freezers and cold rooms were requested by a majority of the respondents who insisted that without fresh fish from the fishermen, losses would continue to be encountered at other downstream nodes of the value chains. Processors of fried and dried fish requested for improvement of infrastructure such as drying racks and provision of high capacity processing infrastructure to reduce the delays during processing occasioned by the use of small equipment. Fishermen requested the provision of modern fishing vessels with inbuilt cold rooms and/or the provision of cooler boxes with sufficient capacity to arrest spoilage during fishing and while on transit to the landing sites. Infrastructural development and provision of preservation equipment across the value chains were suggested as the main intervention which would enhance mitigation against the losses. This aligns with recommendations from related studies proposing the provision of requisite post-harvest management infrastructure as a strategy to reduce losses, particularly among artisanal fishing communities (Alhaji *et al.*, 2015; Odoli *et al.*, 2019). Capacity building of fish value chain actors on the best practices in fish handling, preservation and processing was also identified as a major intervention that could contribute significantly towards the reduction of post-harvest losses (Keerthana *et al.*, 2022).

Conclusion and recommendations

The study revealed the occurrence of significant post-harvest losses occurring along the three value chains evaluated and at all the representative landing sites. These losses mainly occurred in the fresh fish value chain resulting in spoilage during the subsequent trading and

Table 3. Summary of the key factors contributing to high post-harvest losses at all the sampled landing sites.

Factor	Responses	
	No.	%
Lack of cold chain equipment/ infrastructure including cold rooms, freezers and cooler boxes	35	35%
Unfavourable weather conditions during sardine drying	10	10%
Delays during fishing resulting in commencement of fish spoilage before hauling the fish in	28	29%
Lack of proper fish-handling skills at the landing/ processing site	15	15%
Inadequate drying racks and sardine handling infrastructure	10	10%

processing stages in the value chain. Quality losses in the fresh fish supply chain were largely attributed to lack of adequate fish preservation infrastructure such as ice production machines, cooler boxes, freezers and cold rooms. The inadequacy of processing infrastructure further contributed to losses in the dried fish value chain where sardine processors were relegated to drying fish on the ground due to the insufficiency of drying racks, resulting in contamination and high losses, especially during bumper harvest seasons. Improving the fish preservation infrastructure at all the landing sites, coupled with continuous capacity building of the fish value chain actors on the best practices in fish handling are recommended as key mitigation measures against PHFLs in Kwale County. The incorporation of the load tracking method in subsequent studies is recommended to enable the quantification of the losses occurring along the value chains and inform the implementation of target-based mitigation techniques aimed at reducing the losses to a measurable extent.

References

Adewolu MA, Adoti AJ (2010) Effect of mixed feeding schedules with varying dietary crude protein levels on the growth and feed utilization of *Clarias gariepinus* (Bruchell, 1822) fingerlings. *Journal of Fisheries and Aquatic Science,* 5(4): 304–310 [doi:10.3923/jfas.2010.304.310]

Akande G, Diei-Ouadi Y (2010) Post-harvest losses in small-scale fisheries: case studies in five sub-Saharan African countries. FAO Fisheries and Aquaculture Technical Paper. No. 550. FAO, Rome. 72 pp. Retrieved from https://catalogue.nla.gov.au/Record/5196714

Alhaji TA, Jim-Saiki LO, Giwa JE, Adedeji AK, Obasi EU (2015) Infrastructure constraints in artisanal fish production in the coastal area of Ondo State, Nigeria. *International Journal of Research in Humanities and Social Studies*, 2(5): 22-29

Diei-Ouadi Y, Holvoet K, Randrianantoandro A (2014) A decisive impact in natural resource sustainability: Key gender considerations in post-harvest fisheries. In F Bojang, A Ndeso-Atanga (eds), Nature & Faune: Enhancing natural resources management for food security in Africa (1st ed). Food and Agriculture Organization of the United Nations, Vol. 29, Accra. pp 39–44

Diei-Ouadi Y, Mgawe YI (2011) Post-harvest fish loss assessment in small-scale fisheries: A guide for the extension officer FAO Fisheries and Aquaculture Technical Paper. No. 559. FAO, Rome. 93 pp

FAO (2020) The State of World Fisheries and Aquaculture 2020: Sustainability in action. Food and Agriculture Organization [https://doi.org/10.4060/ca9229en]

Ikape SI, Cheikyula JO (2017) Fish spoilage in the tropics: A review. *Octa Journal of Biosciences*, 5(2): 34–37

Johnson DR, Mutua Nguli M, Kimani EJ (1982) Response to annually reversing monsoon winds at the southern boundary of the Somali Current. *Deep Sea Research*, 29(10): 1217–1227 [https://doi.org/10.1016/0198-0149(82)90091-7]

Keerthana PS, Soorya G, Rubeena R, Rinu F, Kavya S, Nisha R, Pooja U, Teena E, Gifty T, Arun Das NH, Dinesh K, Safeena MP, Sreekanth GB (2022) Post-harvest losses in the fisheries sector-facts, figures, challenges and strategies. *International Journal of Fisheries and Aquatic Studies*, 10(4):101-108 [https://doi.org/10.22271/fish.2022.v10.i4b.2691]

Kimani E, Aura C, Okemwa G (eds) (2018) The status of Kenya Fisheries: Towards sustainability exploitation of fisheries resources for food security and economic development. Kenya Marine and Fisheries Research Institute (KMFRI), 135 pp. Retrieved from https://aquadocs.org/handle/1834/16123

Kruijssen F, Tedesco I, Ward A, Pincus L, Love DC, Thorne-Lyman AL (2020) Loss and waste in fish value chains: A review of the evidence from low and middle-income countries. *Global Food Security*, 26: 100434 [https://doi.org/10.1016/j.gfs.2020.100434]

Kumolu-Johnson CA, Ndimele PE (2011) A Review on Post-Harvest Losses in Artisanal Fisheries of Some African Countries. *Journal of Fisheries and Aquatic Science*, 6: 365-378

Manyungwa-Pasani CL, Hara M, Sloans K (2017) Women's participation in fish value chains and value chain governance in Malawi: A case of Msaka (Lake Malawi) and Kachulu (Lake Chilwa), Working Paper 45. PLAAS, UW, Cape Town.

Mavuru A, Mhlanga L, Nhiwatiwa T (2022) An assessment of post-harvest fish losses (PHFLs) in the artisanal fishery of Lake Kariba, Zimbabwe. *Scientific African*, 16: e01124 [https://doi.org/10.1016/j.sciaf.2022.e01124]

Mhanga SF, Mwandya AW (2022) Comparative analysis of physical post-harvest losses of *Rastrineobola argentea* dried using various drying methods along Lake Victoria, Tanzania. *Tanzania Journal of Agricultural Sciences*, 21(1): 129-137

Morrissey MT (ed) (1988) Postharvest Fishery Losses. Proceedings of an International Workshop Held at the University of Rhode Island. ICMRD Kingston, Rhode Island.

Mramba RP, Mkude KE (2022) Determinants of fish catch and post-harvest fish spoilage in small-scale marine fisheries in the Bagamoyo district, Tanzania. *Heliyon*, 8(6): [https://doi.org/10.1016/j.heliyon.2022.e09574]

Nyawade OB, Were-Kogogo P, Owiti P, Osimbo H, Daniel AO (2021) Elusive fish catch and vulnerable livelihoods: Status of fishing and fisheries industry among marine south coast communities of Kwale, Kenya. *Archives of Agriculture and Environmental Science*, 6(2): 149–159 [https://doi.org/10.26832/24566632.2021.060206]

Odoli C, Owiti H, Kobingi N, Obiero M, Ogari Z, Mugo JN, Nyamweya CS, Aura CM (2019) Post-harvest interventions in small-scale fisheries: a boon or bane to food and nutritional security in Kenya? *Food Security*, 11(4): 855–868 [https://doi.org/10.1007/s12571-019-00950-x]

Prodhan MH, Khan A, Palash S, Rahman T (2022) Nature, extent, and causes of post-harvest losses at fisher and farmer level: An in-depth study. *Aquaculture*, 550: 737856 [https://doi.org/10.1016/j.aquaculture.2021.737856]

Purcell SW, Pomeroy RS (2015). Driving small-scale fisheries in developing countries *Frontiers in Marine Science*, 2: 44 [https://doi.org/10.3389/fmars.2015.00044]

Shawyer M, Medina PAF (2003) The use of ice on small fishing vessels. FAO Fisheries Technical Paper. No. 436. FAO, Rome. 108 pp

Tesfay S, Teferi M (2017) Assessment of fish post-harvest losses in Tekeze dam and Lake Hashenge fishery associations: Northern Ethiopia. *Agriculture and Food Security*, 6(1): 1-12 [https://doi.org/10.1186/s40066-016-0081-5]

Tilley A, Cohen PJ, Akester MJ, Batalofo M, Notere Boso D, Cinner J, Dos Reis Lopes J, Duarte A, Eriksson H, Gomese C, Grantham R, Hunnam K, Khan A, Kleiber DL, Lau J, Lawless S, Haque AM, Mills DJ, Morrison T, … Phillips MJ (2021) Increasing social and ecological resilience of coastal fisheries. WorldFish (WF). Retrieved from https://digitalarchive.worldfishcenter.org/handle/20.500.12348/5017

Ward AR, Jeffries DJ (2000) A manual for assessing post-harvest fisheries losses. Manual. Natural Resources Institute,

Chatham, UK.

Williams MJ (2010) Gender dimensions in fisheries management. In: RQ Grafton, R Hilborn, D Squares, M Tait and M Williams (eds) Handbook of Marine Fisheries Conservation and Management. Oxford, Oxford University Press.

Wood CD (1984) Prévention des pertes de poisson traité. FAO, Document Technique Sur Les Pêches (FAO) Fre No. 219. Retrieved from https://scholar.google.com/scholar_lookup?title=Pr%C3%A9vention+des+pertes+de+poisson+-trait%C3%A9&author=+Wood%2C+C.D.&publication_year=1984

Appendixes

Appendix 1. IFLAM Tool: Observation/ Key Informant Interview Guide.

The target: Conduct a pilot baseline survey to quantify fish post-harvest losses in Kwale County (Vanga, Jimbo, Shimoni, Gazi and Mkunguni) to inform management by 30th June 2020 (30%)

Phase One: Informal Fish Loss Assessment Method

Observation Guide

Landing site.....Observer.....Date.....

1. What are the main types of fishing vessels used?

Fishing vessel	Size(M)	Propulsion mode	Construction Material	Number of vessels	Photo taken

Are oil and fuel kept separate in the fishing vessels?

.....

2. What are the main types of fishing gear used?

Fishing gear	Mesh/ Hook size	Photo taken

What are the five main species harvested?

Species	Approx. % of Total Catch	Photo taken

What are the measurement units used for the catch?.....

3. What type of containers are used to hold the harvest during transportation to the landing site? Indicate the number of observations for each based on whether each has ice or not.

WITHOUT ICE			WITH ICE		
Type of holding container	Number observed	Photo taken	Type of holding container	Number observed	Photo taken

Are fish handled carefully to avoid damage?.....

4. How many observations of fish icing after landing or lack thereof are observed?

   Fish icing observations (Number): .....

   Lack of fish icing observations (Number):.....

5. Are the insulated storage facilities, (if present) adequate? .....

   .....

6. Is the landed fish gutted at sea or at the landing site?

Gutting stage	Number of observations	Photo taken
At sea		
At the landing site		
At market		
By the consumer		

Approximately how long does it take to offload and preserve the fish prior to processing/sale?

.....

7. How is the fish processed/ preserved after landing?

Preservation	Processing

Are fish being processed adequately?.....

.....

8. Describe the personal hygiene of crew, handlers and processors?

.....

9. Where are fish placed during processing?

Surface	Number of observations	Photo taken
Directly on the ground		
On rocks		
On fishing nets		
On the floor		
On clean surfaces		
On a clean mat or canvas		
Other:		

What is the source(s) of water used during handling of the fish?

.....

10. Are sanitary conditions adequate? [1]Yes [2]No Elaborate

.....

.....

11. Which animals are wandering freely where fish are handled or processed, etc.?

    .....

12. Which pests/insects are noticeable at the fish landing/processing site etc.?

    Landing.....

    Processing.....

13. How are harvested fish isolated from potential contaminants?

    .....

14. Are landed fish protected from direct solar insolation?

15. How are fish protected from the rain?

    .....

16. What type of containers are used to hold the harvest during transportation to the market? Indicate the number of observations for each in the table below depending on whether the container contains ice or not.

WITHOUT ICE				**WITH ICE**		
Type of holding container	**Number observed**	**Photo taken**		**Type of holding container**	**Number observed**	**Photo taken**

How are fish transported and does this cause any damage or other loss?

Transport means	**Description of damage/loss caused**

What mitigation strategies are being used at the site to control losses?

.....

17. How effective are loss reduction measures?

    .....

    .....

Appendix 2

PHFLA using the Questionnaire Loss Assessment Method (QLAM)

Questionnaire No……Interviewer……..……Date……BMU……Landing Site……

Name	
Gender	[1] Male [2] Female
ID number	
Year of Birth	
Village	
Cell phone Number	
Role	[1] Fish farmer [2] Mama Karanga [3] Fish processor [4] Fish shop owner [5] Fresh fish Monger [6] Other (specify)
BMU Official	[1] Yes (specify position) …… [2] No

For how long have you been engaged in fishing/ fish selling/ fish processing activities?

1. Where have you been fishing/ purchasing the fish for sale or processing (most of the time)?
2. How many days in a week do you fish/ sell/ process fish?

1		2	3	4	5	6	7

On average, how many kilos of fish do you catch / buy for sale/ process per day?

During high season (Kaskazi)		**During low season (Kusi)**	
Lowest	**Highest**	**Lowest**	**Highest**

On average, how many hours per day do you spend at fishing ground/ or purchasing fish @ the landing site?

During high season (Kaskazi)		**During low season (Kusi)**	
At least	**At most**	**At least**	**At most**

On average, how many hours do you spend to transport the fish from the fishing ground to the landing site OR from the landing site to the processing/selling site per day?

During high season (Kaskazi)		**During low season (Kusi)**	
At least	**At most**	**At least**	**At most**

What are the **5** main species of fish caught/ sold/ processed?

Fishermen Only	Fresh fish traders only	Fish processors only
8. a. Type of fishing vessel: b. Propulsion mode:	**8**a. Type of trade [1] Retail [2] Wholesale [3] Both b. Location of market(s):	**8.** Main processing method:[1] Frying [2] Boiling then drying [3] Salting then drying [4]
9. a. Main fishing gear(s) used: b. How long does it take to haul in a single batch of fish using this gear?	**9.** Market type:[1] Open[2] Shop [3] Door-to-door [4] Institutions [5] Other	**9.** How do you prepare the fish for processing? [1] Degutting [2] Descaling [3] Cleaning [4] Salting [5] Other:
10. On average, what proportion of the catch do you keep for subsistence per day?	**10.** Average time to market (s): Nearest……..Farthest……..	**10.** How long do you take to prepare the fresh fish before frying starts?
11a. How often do you discard fish while at: i. Sea:**1.**Daily**2.**Weekly**3.**Monthly**4.**Rarely**5.**Never ii.Landing: **1.**Daily**2.**Weekly**3.**Monthly**4.**Rarely**5.**Never **11b.** What amounts of discards do you lose at a go? Discards at a go (Sea): Min…….kg; Max.....kg Discards at a go (Landing): Min.....kg; Max.....kg	**11. a.** How many hours/ days does it take you to clear off (sell) a single batch of fresh fish?	**11.** How many hours/ days does it take you to clear off (sell) a single batch of processed fish?

Fishermen Only				
12	**Selling Price of Harvested Fish**			
	High season Ksh./kg		Low season Ksh./kg	
	Highest	***Lowest***	***Highest***	***Lowest***

Fresh fish traders only				
12	**Buying Price of Fresh Fish**			
	Low season Ksh./kg		High season Ksh./kg	
	Highest	***Lowest***	***Highest***	***Lowest***
	Selling Price of Fresh Fish			
	High season Ksh./kg		Low season Ksh./kg	
	Highest	***Lowest***	***Highest***	***Lowest***

Fish processors only				
12	**Buying Price of Fresh Fish**			
	Low season Ksh./kg			
	Highest	***Lowest***	***Highest***	***Lowest***
	Selling Price of Fresh Fish			
	High season Ksh./kg		Low season Ksh./kg	
	Highest	***Lowest***	***Highest***	***Lowest***

What factors contribute to price fluctuations?.....

.....

.....

.....
.....

1. Have you ever lost fish due to spoilage? **[1]** Yes **[2]** No
2. If yes, how many kilos of fish have you ever lost at a go? **Min.**:.....kg of .....kg **Max..**:.....kg of .....kg
3. If yes, how often do you encounter fish spoilage? **[1]** Daily **[2]** Once weekly **[3]** Several times in a week **[4]** Once monthly **[5]** Twice monthly **[6]** Once in a while (Specify).....
4. If yes, at what point (s) along the value chain do you encounter the highest proportion of the losses? **[1]** During fishing **[2]** During transportation of the fish to the landing site **[3]** During transportation of fresh fish to the market **[4]** While waiting to sell the fresh fish at the market **[5]** Before processing **[6]** During processing **[7]** During transportation of fresh fish to the market **[8]** While waiting to sell the processed fish at the market **[9]** Other(specify).....
5. If yes, how do you handle the spoilt fish? **[1]** Discard **[2]** Salting and drying **[3]** Consumed at home **[4]** Sold fresh at throw away prices **[5]** Other (specify) .....
6. If sold, how much money do you make from the sale of a batch of dried fish(*'ng'onda'*) or spoilt fresh fish?

Spoilt Fish (Fresh)		**Dried Spoilt Fish (Ng'onda)**	
Lowest: ..... Ksh./kg	Highest: .....Ksh./kg	Lowest: .....Ksh/kg	Highest: .....Ksh./kg

What factors do you think contribute to fish spoilage.....

.....
.....

7. How do you process/preserve your fish (especially fresh fish) to minimize/ prevent spoilage?

1. Icing	**2.** Freezing	**3.** Gutting	**4.** Washing	**5.** Beheading	**6.** Filleting	**7.** Salting	**8.** None	**9.**Other

On average, how much money do you spend per day on preservation of fish to minimize spoilage?

During high season (Kaskazi)		**During low season (Kusi)**	
Lowest: Ksh.....	Highest: Ksh.....	Lowest: Ksh.....	Highest: Ksh.....

What challenges do you encounter while mitigating post-harvest fish lossess and what strategies would you propose to counter these challenges?

a.Challenges encountered during fish preservation	b.Strategies proposed / Recommendations to mitigate spoilage