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ORIGINAL ARTICLE OPEN ACCESS

Impact of Load Shedding on Fresh Fish Suppliers and Consumers in Chinsali District, Zambia

Mwansa Kambili[1,2] | Chewe Bwalya[1,2] | Joyce Mbewe[1] | Malawo Mweemba[2,3] | Emmanuel Nkweto[2] | Chisomo J. Phiri[4] | Joseph Mphande[2,5] | Oliver J. Hasimuna[1,2,5]

[1]Department of Zoology and Aquatic Sciences, School of Natural Resources, Copperbelt University, Kitwe, Zambia | [2]Department of Agriculture and Aquatic Sciences, Copperbelt University, Kapasa Makasa University Campus, Chinsali, Zambia | [3]Department of Biomaterials Science and Technology, School of Natural Resources, Copperbelt University, Kitwe, Zambia | [4]National Aquaculture Research and Development Centre, Department of Fisheries, Ministry of Fisheries and Livestock, Kitwe, Zambia | [5]Department of Aquaculture and Fisheries Sciences, School of Agricultural Sciences, Palabana University, Lusaka, Zambia

Correspondence: Oliver J. Hasimuna (oliverhasimuna@gmail.com)

Received: 8 November 2025 | **Revised:** 1 April 2026 | **Accepted:** 7 April 2026

Keywords: consumer behaviour | fish suppliers | load shedding | perishability | postharvest losses | technological intervention | Zambia

ABSTRACT

Fresh fish is highly perishable and requires an efficient cold chain to maintain quality and safety. In Zambia, recurrent load shedding disrupts refrigeration and storage systems, increasing the risk of post-harvest losses and food safety. This study examined the effects of load shedding on fresh fish handling, supply and consumer access in Chinsali District of Muchinga Province, Zambia, in June 2024. Semi-structured questionnaires were administered to fish suppliers ($n = 19$) and consumers ($n = 169$), and data were analysed using descriptive statistics and the chi-square test of independence. Results showed that 93% of suppliers and 84% of consumers were negatively affected by load shedding, mainly through accelerated spoilage, inconsistent supply and increased operational costs. Consumers responded by purchasing smaller quantities or shifting to alternative protein sources, whereas suppliers adopted coping measures, such as reducing inventory and investing in alternative energy options. The findings highlight the vulnerability of the fresh fish value chain to energy disruptions and emphasize the need for improved preservation technologies, training in post-harvest handling and policy support to strengthen cold-chain resilience in rural aquaculture and fisheries markets.

1 | Introduction

Fish production and marketing have played a central role in human sustenance for centuries (Agbebi and Adetuwo 2018). Globally, fish remains an essential component of the human diet owing to its rich nutritional profile, particularly in developing countries where it significantly contributes to reducing malnutrition (Ogundiran et al. 2014; Troell et al. 2014; Mphande and Chama 2015; Hasimuna, Mphande, Lengwe, et al. 2025; Hasimuna, Mphande, Maulu, et al. 2025). Compared with other animal protein sources, such as poultry and beef, fish provides easily digestible protein, essential amino acids, vitamins and minerals, including calcium and iron (Abolagba and Nuntah 2011; Maulu et al. 2020, Maulu, Musuka, et al. 2024; Hasimuna et al., 2024). In countries such as Zambia, where starchy foods dominate household diets, fish serves as a vital supplement that improves nutrition and food security among low-income populations (Idris et al. 2010; Beveridge et al. 2013; Maulu, Musuka, et al. 2024).

Aquaculture has emerged as the fastest growing food production sector globally and continues to expand its contribution to food fish supply (Naylor et al. 2021; Gabriel et al. 2022; Nabi et al. 2025). In Zambia and the Southern Africa, aquaculture plays an important role in improving household food security, supporting livelihoods and providing micronutrient-rich foods (Hasimuna et al. 2023; Maulu, Hasimuna, et al. 2024).

Fish and fish products contribute more than 20% of the total animal protein intake in the country, making them indispensable to the diets of many communities (Maulu et al. 2020; Nölle et al. 2020; Maulu, Hasimuna, et al. 2024). Despite its nutritional and economic importance, fish is highly perishable and prone to rapid microbiological and enzymatic spoilage, which reduces its quality and market value (Daluwatte 2018; Ali et al. 2022; Wang and Zheng 2025). Substantial post-harvest losses occur due to inadequate handling, processing, packaging, transportation and storage facilities, particularly in resource-constrained settings where access to cold chain infrastructure remains limited (Entee 2015; Akintola and Fakoya 2017; Kitinoja 2016; Lokuruka 2016; Musuka et al. 2023).

In Zambia, the fish marketing system involves a complex network of intermediaries, including wholesalers, retailers and market vendors operating across multiple aggregation points, such as township, village and roadside markets (Asogwa and Asogwa 2019; Kafumukachemilu 2021). Along this chain, fish is subjected to repeated handling processes, including packaging, loading, unloading and redistribution, each of which may appear minor in isolation but collectively contribute to significant quality deterioration and economic loss (Ali et al. 2008; Golgeci and Gligor 2017).

The current energy crisis in Zambia, characterized by recurrent load shedding, has further intensified post-harvest challenges in the fish value chain (Pambwe 2021; Kintu 2022; Musonda 2025). A reliable electricity supply is essential for operating cold storage systems that maintain the freshness and nutritional quality of fish during storage and distribution (Forkuoh and Li 2015; Ajibola et al. 2021). Frequent power outages, reaching up to 20 h per day during the study period, implemented by the Zambia Electricity Supply Corporation (ZESCO) Limited, have disrupted business operations, household food systems and livelihood activities across the country (Chitandula et al. 2024; Umar and Kunda-Wamuwi 2019). Fresh fish, being highly perishable, is particularly vulnerable to such disruptions, resulting in increased spoilage, reduced availability and financial losses for traders and consumers alike (Tesfay and Teferi 2017).

Although load shedding remains a persistent national challenge in Zambia due to El Niño-induced drought that has led to low water levels in Lake Kariba, which supplies more than half of the country's hydropower (Ghosh et al. 2025; ZESCO 2026), there is limited empirical research assessing its effects on post-harvest fish losses and consumer behaviour. Existing studies have largely focused on general energy insecurity, with little attention to its specific implications for perishable aquatic food systems and small-scale market actors (Sovacool 2012; FAO 2020). Understanding these dynamics is essential for developing context-appropriate interventions that enhance the resilience of fish supply chains, protect food quality and support the livelihoods of affected communities.

Therefore, this study aimed to generate empirical evidence on the implications of load shedding for the fish value chain in Chinsali District by pursuing the following specific objectives:

1. To assess perceived operational and economic effects of load shedding on fresh fish suppliers and consumers in Chinsali District.
2. To analyse changes in purchasing behaviour, storage practices and consumption patterns in response to electricity disruptions.
3. To identify feasible strategies for enhancing the resilience of fresh fish supply chains under persistent energy shortages.

2 | Materials and Methods

2.1 | Study Site

The study was conducted in Chinsali District of Muchinga Province, Zambia, located at approximately 356,000–364,000 mE and 1,100,000–1,240,000 mN (UTM Zone 35S, WGS 84 datum) (Figure 1). The district is characterized by a growing fisheries and aquaculture sector that contributes to local food security and livelihoods. Capture fisheries are primarily conducted in the Chambeshi River and surrounding water bodies, whereas aquaculture is practiced mainly through small-scale pond culture across several wards of the district. Recent district reports indicate that approximately 1000 farmers in Chinsali are engaged in fish farming, managing an estimated 2500 fishponds distributed across the district, with total fish production estimated at 5000 kg per quarter (Musaka et al. 2023).

Chinsali is connected to the national electricity grid operated by ZESCO Limited, a state-owned utility managing the country's power generation, transmission and distribution. The national grid integrates electric generating power plants from various parts of Zambia, including the 1-MW Shiwang'andu hydropower station in nearby Shiwang'andu District. During the study period, load shedding reached up to 20 h per day on average nationally, and Chinsali experienced frequent scheduled outages that affected households, businesses and cold-chain-dependent activities.

Fresh fish in Chinsali District is primarily supplied by fish from capture fisheries, such as Lake Bangweulu, Lake Tanganyika and the Luangwa River, as well as by aquaculture producers in the surrounding areas. Transport of fish from landing sites and farms to Chinsali is typically conducted using refrigerated trucks or cooler boxes with ice, primarily via road transport. Transit times vary depending on source location and road conditions, often ranging from several hours to more than 1 day. At the supplier and retail levels, fish is commonly stored in chest freezers or refrigerators that rely on grid electricity. At the household level, consumers predominantly store fish in domestic refrigerators or freezers. Fish trade forms an important part of the local economy, with both suppliers and consumers depending on reliable electricity for cold storage, preservation and household consumption.

2.2 | Ethical Approval

Participation was voluntary, and informed consent was obtained verbally. For responses collected using Kobo, consent was under-

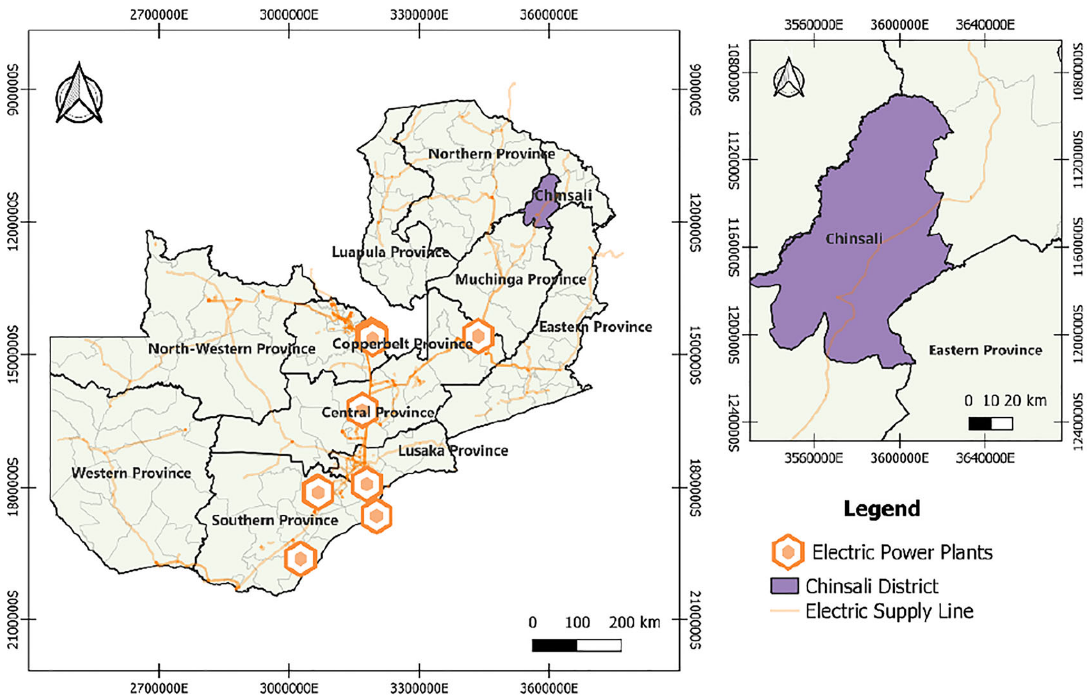

FIGURE 1 | Map of Zambia showing the location of Chinsali District in relation to major electric power plants and the national electricity supply lines.

stood to have been given when participants chose to continue with the questions and submit the form. Participants were informed that they could stop taking part at any time without any negative consequences. No personal identifiers were recorded, and all responses were kept anonymous. Data collected through Kobo were stored securely on password-protected devices and were accessible only to the research team.

2.3 | Sampling Procedure

A random sampling procedure was employed to select fish suppliers and consumers in Chinsali. Nineteen fish suppliers were randomly selected from 20 active registered suppliers. One supplier was unavailable during the data collection period. For consumer selection, households located within the catchment area of selected suppliers were first listed with the assistance of local guides. The required sample size ($n = 169$), calculated using the equation by Cochran (1977) (Equation 1), was obtained by assigning numbers to households and selecting them randomly. Where multiple eligible respondents were present in a household, one respondent was randomly selected:

$$n = \frac{NZ^2 P(1-p)}{E^2(N-1) + Z^2 p(1-p)} \qquad (1)$$

where n is the required sample size, p is the population proportion (assumed to be 0.50, to provide the maximum sample size), Z is 1.96 for 95% confidence level, and E is a 5% margin of error.

2.4 | Data Collection

Data were collected using a single semi-structured questionnaire designed to capture information from both fish suppliers and consumers. The questionnaire consisted of five sections: Section A covered demographic characteristics; Section B focused on the impacts of load shedding on fish suppliers; Section C examined the impacts of load shedding on fish consumers; Section D addressed coping strategies and emerging opportunities; and Section E allowed for additional comments from respondents. Sections B and C contained primarily single-choice items, in which respondents selected one response option. In Section D, respondents were allowed to select multiple applicable responses. Data were collected using both face-to-face and online questionnaires. Of the total responses, 150 were obtained through face-to-face interviews, whereas 19 were collected via the online survey. The questionnaire content, structure and response options were identical across both data collection modes. Both qualitative and quantitative data were collected. Prior to data collection, the questionnaire was pre-tested and refined to ensure clarity, relevance and the ability to generate the intended information. The pre-testing process helped to identify repetitive items, ambiguous questions and areas requiring simplification, leading to revisions that improved consistency and reduced respondent burden (Mphande et al. 2023; Hasimuna, Mphande, Lengwe, et al. 2025; Hasimuna, Mphande, Maulu, et al. 2025). The final version of the questionnaire was administered in June 2024. For respondents who did not speak English fluently, the questionnaire was translated into Bemba, the predominant local language in Chinsali, and administered orally by trained enumerators. Completed questionnaires were coded and entered into Kobo Toolbox for data management and subsequent analysis.

TABLE 1 | Demographic information of fresh fish consumers and suppliers.

Variables	Category	Number ($n = 169$)	Percentage
Consumers	Male	35	21
	Female	134	79
Variables	**Category**	**Number ($n = 19$)**	**Percentage**
Suppliers	Male	15	79
	Female	4	21

2.5 | Data Analysis

To extract meaningful insights from the gathered data, Microsoft Excel was utilized for descriptive analysis, and cross-tabulations were conducted in IBM SPSS Statistics (v29). Proportions in the form of percentages were generated to summarize the fish consumers' and suppliers' perspectives on the impact of load shedding. The data were organized into frequency tables and figures using Microsoft Excel to facilitate a comprehensive understanding of the collected information. A chi-square test of independence was conducted to examine the association between the use of alternative power supply methods and the perceived impacts of load shedding. Respondents were grouped on the basis of whether they used alternative power supply methods (yes/no), and the distribution of load-shedding impact ratings (measured on a five-point Likert scale) was compared between the two groups. Where assumptions of the chi-square test were violated due to sparse cell counts, the Fisher–Freeman–Halton exact test was applied. The level of statistical significance was set at $p < 0.05$. Effect size was assessed using Cramér's V to determine the strength of association. This approach enabled a comprehensive analysis of the data, providing a clear overview of the patterns and trends related to the impacts of load shedding on the consumers and suppliers of fish.

3 | Results

3.1 | Demographic Information of Fresh Fish Consumers and Suppliers

The demographic information of consumers and suppliers are summarized in Table 1. Among consumers (n = 169), females (n = 134) predominated, accounting for 79%, whereas males (n = 35) represented 21%. In contrast, the majority of suppliers (n = 19) were male (n = 15, 79%), with females (n = 4) constituting only 21%.

3.2 | Reported Effects of Load Shedding on Fish Suppliers and Consumers

Electricity outages influenced fresh fish supply operations and consumption. The majority of the interviewed suppliers (n = 17, 89%) reported disruptions to their business activities citing reduced refrigeration capacity, shortened storage periods and increased risk of product spoilage, whereas only two suppliers (11%) who had alternative energy sources were unaffected. Similarly, most consumers (84%, n = 142) experienced challenges in safely storing or preparing fresh fish, with just 27 consumers (16%) reporting no impact.

3.3 | Impact of Load Shedding on Fish Suppliers

Electricity outages posed several operational challenges for fish suppliers (Figure 2). The most frequently reported challenge was difficulty in maintaining fish quality (38%), primarily due to inadequate refrigeration and prolonged exposure to ambient temperatures. Approximately one-third of suppliers (31%) reported increased operational costs from reliance on alternative energy sources, such as generators. In addition, 15% of suppliers reported reduced sales, whereas a further 15% reported fish spoilage, both of which contributed to direct economic losses.

3.4 | Measures Adopted by Suppliers to Cope With Load Shedding

The most common strategy was reducing inventory levels, reported by eight suppliers (42%). Five suppliers (26%) adjusted their operating hours to align with power availability. Similarly, reliance on generators to maintain cold storage was reported by five suppliers (26%). Two respondents (11%) invested in solar power systems to provide a more sustainable energy source. Other strategies included increasing purchases of ice (one supplier, 5%), acquiring a long-lasting refrigerator (one supplier, 5%) and installing a cold room (one supplier, 5%).

3.5 | Effect of Load Shedding on Consumers

The effects of load shedding on fish consumers (n = 169) in Chinsali District showed marked variations among the sampled population. A greater proportion of respondents (60%, n = 101) reported fish spoilage due to a lack of refrigeration. Reduced fish quality was reported by 14% of consumers (n = 14), whereas both reduced fish availability and increased fish prices affected 13% of respondents (n = 22). 'Fish spoilage' referred to fish that had become unfit for consumption due to microbial decomposition or prolonged storage, whereas 'reduced fish quality' referred to deterioration in desirable attributes, such as texture, colour, taste or freshness without necessarily rendering the fish inedible.

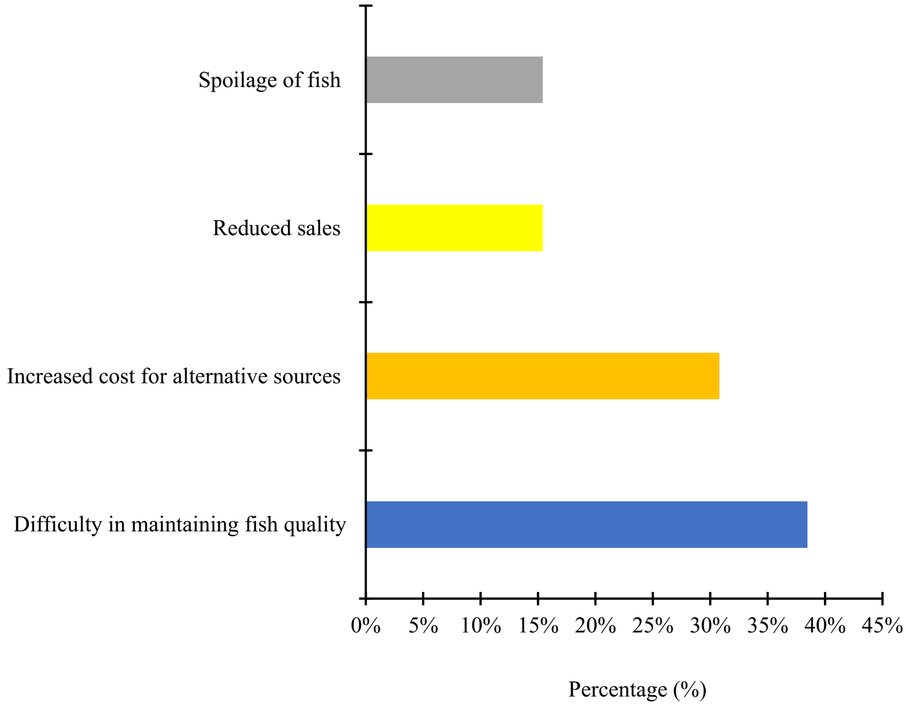

FIGURE 2 | Effects of load shedding among fish suppliers in Chinsali District.

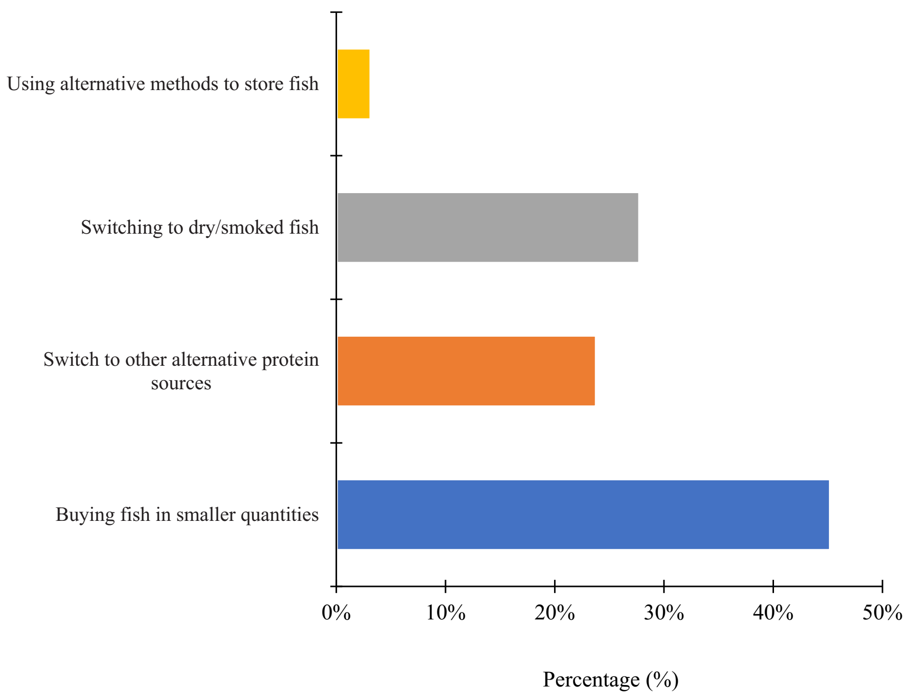

FIGURE 3 | Measures adopted by consumers in response to load shedding in Chinsali District, Zambia.

3.6 | Measures Adopted by Consumers in Response to Load Shedding

The strategies adopted by consumers ($n = 169$) to cope with load shedding are presented in Figure 3. The most commonly reported measure was purchasing fish in smaller quantities ($n = 76$, 45%), followed by switching to dry or smoked fish ($n = 47$, 28%). A further 24% of respondents ($n = 41$) reported substituting fish with other protein sources, whereas 3% ($n = 5$) employed alternative methods to store fresh fish. The use of alternative methods to store fresh fish included practices, such as temporary shade storage, use of cooler boxes and wet sack covering, which were mainly employed as a temporary strategy where cold storage facilities were unavailable.

TABLE 2 | Association between use of alternative power supply methods and the impact of load shedding in Chinsali District.

Alternative power supply	1 (Not significant)	2 (Somewhat significant)	3 (Neutral)	4 (Significant)	5 (Very significant)	Total
No	3 (3.2%)	12 (12.9%)	28 (30.1%)	39 (41.9%)	11 (11.8%)	93 (81.6%)
Yes	9 (42.9%)	4 (19.0%)	4 (19.0%)	3 (14.3%)	1 (4.8%)	21 (18.4%)
Total	**12 (10.5%)**	**16 (14.0%)**	**32 (28.1%)**	**42 (36.8%)**	**12 (10.5%)**	**114 (100%)**
Chi-square test				χ^2	**df**	***p* value**
Pearson chi-square				31.137	4	<0.001
Likelihood ratio				24.817	4	<0.001
Fisher–Freeman–Halton exact test				23.805	—	<0.001
Linear-by-linear association				21.150	1	<0.001
Effect sizes				**Value**		***p* value**
Cramer's *V*				0.523		<0.001

3.7 | Association Between the Use of Alternative Power Supply Methods and the Impact of Load Shedding

The association between the use of alternative power supply and perceived impact was statistically significant (Table 2). The Pearson chi-square test indicated a strong association between the variables ($\chi^2 = 31.137$, df = 4, $p < 0.001$). This result was supported by the likelihood ratio test ($\chi^2 = 24.817$, df = 4, $p < 0.001$) and the Fisher–Freeman–Halton exact test ($p < 0.001$). Additionally, the linear-by-linear association test demonstrated a significant ordinal trend between the variables ($\chi^2 = 21.150$, df = 1, $p < 0.001$). Effect size measures further indicated that the strength of the relationship was substantial. Cramer's V ($V = 0.523$, $p < 0.001$) suggests a strong association between the adoption of alternative power supply methods and respondents' perceptions of the impact of power supply.

3.8 | Reported Changes in Fresh Fish Purchasing Behaviour During Load Shedding

The frequency with which consumers ($n = 169$) purchased fresh fish during periods of load shedding showed varied purchasing preferences. Most respondents (41%) preferred purchasing fresh fish once a month, whereas 27% purchased fish only occasionally. Purchases made several times a month accounted for 18% of consumers, and 9% preferred purchasing fresh fish once a week. A smaller proportion of respondents purchased fresh fish several times a week (4%), and daily purchasers represented 1% of the sample population.

3.9 | Opportunities Identified by Fish Suppliers to Mitigate Load-Shedding Impacts

The present study identified several strategies employed by fish suppliers to mitigate the impact of load shedding in Chinsali District. The most frequently reported strategy was training on alternative fish preservation methods (38%), followed closely by government support for alternative energy sources (36%). Improved infrastructure for fish storage was cited by 14% of respondents, whereas community-based solar power initiatives accounted for 12% of responses.

3.10 | Opportunities Identified by Consumers to Mitigate Load-Shedding Impacts

The largest proportion of respondents (30%) identified investment in alternative energy sources as a key opportunity for consumers during periods of load shedding. Shifting from fresh to dry or smoked fish was reported by 30% of consumers, whereas 21% highlighted the need to develop new preservation techniques. Collaboration among suppliers accounted for 2%, and increased community cooperation was reported by one respondent (~1%).

4 | Discussion

4.1 | Demographic Information and Occupation in the Fish Value Chain

The demographic information of respondents and their occupation in the fish value chain in the present study revealed that the majority of fresh fish consumers in Chinsali District were females. This finding contrasts with previous studies that reported a higher proportion of male fish consumers than female consumers (54.1% and 45.9%, respectively) (Wenaty et al. 2018). In this study, this finding can be linked to the central role women in most African societies play in household nutrition and meal preparation, compelling them to make more frequent visits to local markets, increasing their access to fresh fish, which may not always be accessible (Ene-Obong et al. 2017; Maulu et al. 2021). Although awareness of its health benefits, such as supporting child growth and improving family well-being, may further motivate them to consume it more often than men (Harris et al. 2019; Kawarazuka and Béné 2010).

Regarding the gender distribution of fresh fish suppliers, the majority were males. A similar study by Kafumukachemilu (2021) also found that most fish suppliers are male. This indicates that men are more involved in fish production and supply within the fish value chain, reflecting a gendered division of labour. This can be attributed to the capital, physical labour and access to resources, such as shops and cold storage facilities, required to produce and supply fish, which most women are unable to access (Kusakabe and Thongprasert 2022).

4.2 | Impacts of Load Shedding on Suppliers and Consumers of Fish

During the 2024–2025 national load-shedding period in Zambia, several fresh fish suppliers and consumers were impacted. The current study revealed that the majority of suppliers struggled to maintain fish quality and incurred increased operational costs due to the use of alternative electrical power supply methods, such as generators and solar systems. Similar findings were reported by Forkuoh and Li (2015), Kintu (2022), Sule (2021) and Bappah and Adejoh (2024), noting that frequent power outages reduce the efficiency of cold storage facilities, forcing traders of perishable dairy goods to rely on expensive backup energy sources, such as generators, or invest in cold storage units and raising the overall cost of production. This can be attributed to the lack of a continuous electric supply that is required for refrigerators to operate in order to preserve the freshness of fish. Therefore, this situation may have led to an increased demand for generators and solar systems by most suppliers and other electric consumers, which could have resulted in increased costs, especially for suppliers using generators (Sefuka and Haabazoka 2025).

Furthermore, some suppliers experienced reduced sales and fish spoilage as a result of load shedding, consistent with Masule (2022) and Ngoepe-Ntsoane (2025), who emphasized that inadequate electricity supply contributed to decreased profitability among fresh produce traders through reduced sales and product spoilage. This finding can be linked to consumer scepticism about buying spoiled fish from most fish suppliers.

Regarding the impacts of load shedding on consumers of fresh fish in Chinsali District, the present study revealed that the majority of consumers were affected and experienced fish spoilage due to a lack of refrigeration. Most households in Chinsali District rely on electrical supply from ZESCO (Roads and Province, 2020). Therefore, when load shedding occurs, refrigeration is disrupted, promoting fish spoilage to occur rapidly. A similar study in Tanzania by Carlsson et al. (2025) also found that unreliable electricity supply significantly reduced the shelf life of fish and other animal products at the household level. Similarly, in South Africa, Dlamini et al. (2025) observed that frequent load shedding resulted in increased household food wastage due to the inability to maintain the consistent power needed to run cold storage units, such as refrigerators.

4.3 | Measures Adopted by Suppliers to Cope With Load Shedding

Several measures were adopted by fresh fish suppliers to cope with load shedding. The most commonly adopted measures in the present study were reducing inventory and reducing business hours. This finding is similar to a study by Masule (2022), which found that fish traders reduced their inventory during frequent power cuts to avoid fish losing freshness and eventually spoiling. Some suppliers also invested in generators, solar power, long-lasting refrigerators, cold rooms or ice purchases to mitigate the impact of load shedding. These strategies were directly linked to addressing challenges involving maintaining fish quality and increased operational costs that were faced by fresh fish suppliers in Chinsali District. These measures may have reduced the risk of spoilage but decreased the availability of fish to consumers, contributing to price volatility and reduced consumer access and demand, raising operational costs and reducing profitability, particularly for small-scale suppliers with limited capital. Comparable findings were reported by Zulu and Maama (2025), who emphasized that only larger traders and suppliers with higher capital reserves could afford renewable energy and power storage equipment.

4.4 | Measures Adopted by Consumers During Load Shedding

Several measures were adopted by fresh fish consumers to cope with the load shedding in Chinsali District. Our study revealed that the majority of consumers coped with the situation by buying fresh fish in smaller quantities and switching from fresh fish to dry or smoked fish. Suggesting electricity disruptions significantly influences fish consumption patterns, as households fear spoilage. This can be attributed to the ease of consuming smaller quantities of fresh fish immediately after purchase without relying on refrigeration, whereas dry or smoked fish can be stored without refrigeration and take longer to spoil and lose quality (Horner 1997; Maulu et al. 2020; Ahern et al. 2025). Similar findings were reported by Masinga and Madzivhandila (2023) in South Africa, who noted that households adjusted their consumption behaviour during periods of prolonged power outages due to concerns about food spoilage. Similar behavioural adjustments were also noted by Umar and Kunda-Wamuwi (2019), citing that consumers reduced purchasing perishable food and substituted it with dried food or other protein alternatives when faced with unreliable power supply.

4.5 | Association Between the Use of Alternative Power Supply Methods and the Impact of Load Shedding

The present study found a significant association between the use of alternative power supply methods and the impact of electrical power outages in Chinsali District. Respondents who did not use alternative power supply methods apart from using ZESCO-supplied electricity reported that load shedding had a highly significant impact, whereas those who adopted alternative methods, such as the use of solar and generators, were not affected by the electricity power outages. A similar study by Kintu (2022) also found that alternative power sources reduced the impact of load shedding among consumers who are reliant on electricity supplied by ZESCO. These findings indicate that it is important for suppliers and consumers of fresh fish in Chinsali District to find backup power sources during power outages to reduce the impact of load shedding.

4.6 | Frequency of Fresh Fish Purchases Among Consumers

The purchasing frequency of the majority of fresh fish consumers in Chinsali District was altered during the load-shedding period. The current study revealed that the majority of consumers purchased fresh fish once a month and rarely at all during the period. A similar study by Masinga and Madzivhandila (2023) found that during load-shedding periods, most fresh produce consumers in South Africa purchase fresh products only when they want to consume them. This can be linked to storage challenges, as fresh fish is highly perishable and requires refrigeration to maintain quality. As a result, consumers avoided purchasing fresh fish frequently, because they cannot guarantee safe storage without reliable electricity.

4.7 | Opportunities for Suppliers

Among fresh fish suppliers in Chinsali District, several opportunities emerged, including having a backup community-based solar system, having improved infrastructure for fish storage, training on alternative preservation methods and government support for alternative energy sources. This aligns with the previous study by Tembe and Hlengwa (2022), who stated that participants in a survey in South Africa reported having a backup system or systems that combined solar energy and generators to help them mitigate load shedding. Additionally, Kazmi et al. (2019) found that despite the power supply challenges, the proliferation of backup systems has also created unprecedented opportunities for Pakistan's transition to a smarter electricity grid. Solar systems can reduce reliance on the national grid and ensure continuity in cold storage. However, only a few suppliers can afford them.

Improvement of infrastructure for fish storage by investing in modern cold storage facilities or insulated containers could safeguard fish quality and extend shelf life, consistent with the findings of Siddiqui et al. (2024), who emphasized that improved storage infrastructure is crucial for reducing losses and maintaining consumer trust in perishable commodities like fish. Government support for alternative energy sources through policy incentives and subsidies targeting renewable energy adoption in the fisheries sector could strengthen suppliers' capacity to adapt and remain competitive (Tzankova 2021).

4.8 | Opportunities for Consumers

The present study revealed several opportunities that emerged for consumers in response to load shedding. One of the major opportunities was the adoption of alternative energy sources. Similar observations were reported by Rutta (2022), who noted that the integration of solar-powered cold storage improved fish shelf life and stabilized consumer preservation of fresh products, even during power disruptions. This may benefit consumers as it enhances the availability of electricity to power refrigerators. The shift from fresh to dry or smoked fish also presented opportunities for fresh fish consumers. Dried and smoked fish are more affordable, have a longer shelf life and are less reliant on electricity for preservation. This aligns with findings by Adeyeye and Oyewole (2016), who emphasized that smoked fish serves as a critical source of protein for households during periods of limited access to fresh fish. Another opportunity identified was the demand for the development of new preservation techniques, consistent with a review by Siddiqui et al. (2024), where advancements in preservation methods were found to reduce microbial spoilage and improve consumer confidence in fish products. Consumers stand to benefit from safer and higher-quality products if innovations such as improved packaging, use of natural preservatives or modified atmosphere storage are adopted (Getahun et al. 2025; Odediran and Ojebiyi 2017).

4.9 | Limitations

Although this study provides important insights into the effects of load shedding on fresh fish supply chains and consumption, several limitations should be acknowledged. The relatively small supplier sample size ($n = 19$) and the consumer selection approach within supplier catchment areas may limit broader generalization of the findings. Additionally, the use of mixed data collection modes may have introduced minor response variability despite the standardized questionnaire. The study also relied on self-reported impacts and did not include direct measurements of spoilage quantities or monetary losses. Future research incorporating larger samples and objective assessments of economic and product losses would strengthen the understanding of load-shedding impacts on fish value chains.

5 | Conclusion and Recommendations

Load shedding in Chinsali District was reported to affect post-harvest fish quality, supplier operations and consumer purchasing patterns. Suppliers perceived challenges such as increased spoilage, higher costs due to alternative energy use, reduced sales and challenges in maintaining product quality. Consumers reported similar difficulties, including accelerated spoilage, reduced availability of fresh fish and higher prices. Both groups adopted coping strategies such as reducing inventory, purchasing smaller quantities, switching to preserved fish and utilizing generators, solar power, or ice to maintain freshness. To mitigate these impacts, practical interventions for Chinsali could include the deployment of solar direct-drive freezers, provision of insulated fish boxes with organized ice supply and establishment of community solar-powered cold rooms linked to market centres. At the systemic level, stabilizing electricity supply and improving maintenance of energy infrastructure remain essential to reduce post-harvest losses and safeguard food quality and market livelihoods. Advance communication of load-shedding schedules would allow suppliers to better adjust operating hours and help consumers plan purchases to reduce spoilage and shortages, thereby reducing the negative effects on both households and fish businesses.

Author Contributions

Chewe Bwalya: methodology, data curation, formal analysis, software, writing – original draft. **Emmanuel Nkweto**: writing – review and editing, visualization, validation, writing – original draft. **Mwansa Kam-**

bili: methodology, software, resources, project administration, writing – original draft, investigation, formal analysis, funding acquisition, data curation, visualization. **Malawo Mweemba**: data curation, visualization, writing – review and editing, writing – original draft, validation. **Joyce Mbewe**: supervision, writing – original draft, writing – review and editing. **Chisomo J. Phiri**: writing – review and editing, writing – original draft, validation, visualization, data curation. **Joseph Mphande**: methodology, validation, visualization, writing – review and editing, supervision, writing – original draft, data curation. **Oliver J. Hasimuna**: conceptualization, methodology, validation, visualization, writing – review and editing, project administration, formal analysis, resources, supervision, writing – original draft, funding acquisition, data curation.

Acknowledgements

The authors would like to express their gratitude to the staff at Kapasa Makasa University for their invaluable support throughout the study. We also extend our appreciation to the anonymous reviewers for their insightful feedback and constructive comments.

Funding

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All the necessary material is contained in this article.

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