ORIGINAL RESEARCH

Aqua perspectives: stakeholder attitudes and perceptions in live fish transportation practices within the Kenyan fisheries sector

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ABSTRACT. Live fish are in high demand all over the world, especially in China, where quality standards align with consumer preferences. In Kenya, discussions on live fish, particularly in aquaculture-rich regions, are focal points. However, the lack of a systematic approach to transporting live fish poses challenges for stakeholders. This research explores attitudes and perceptions of stakeholders in Kenya regarding the adoption and transportation of live fish, shedding light on transportation procedures and sector challenges. Using a descriptive research design, primary data were collected from diverse aquaculture stakeholders through a questionnaire, addressing their knowledge, perceptions, and attitudes toward live fish transportation in the country. The study unveils varied patterns of live fish transportation in Kenya, influenced by the purpose and distance. Private cars are prominent at 26.3%, with Nyanza and Mombasa leading at 35%. Modified vans are prevalent in Central-Nairobi and Western regions (25% and 22.5%, respectively), while public transport is widespread, especially in Central and Nairobi (25%). Purpose-built live fish vehicles dominate in Western and Nyanza (20% and 17.5%, respectively). Crustaceans like lobsters and crabs are primarily exported from the Coastal region (27.5%). Participants generally assessed their knowledge of live fish transportation as moderate, with a basic understanding of fish welfare. Feedback indicates common practices in live fish transport in Kenya as sealed tanks, plastic bags, and purpose-built vehicles. Temperature and oxygen fluctuations poses a significant challenge during transportation across all regions, particularly in Mombasa and Kisumu. The use of anaesthetics, especially for food fish, is infrequently reported. The study revealed favourable perceptions of stakeholders to live fish transportation and welfare, indicating early adoption. Further research is recommended on fish welfare, best management practices, technological advancements, and interdisciplinary studies to enhance the sustainability of live fish transportation sector and fish welfare in Kenya.

Key words: Live transport, aquaculture, water quality, fish welfare, public attitudes and perception.

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Perspectivas acuáticas: actitudes y percepciones de los actores en las prácticas de transporte de peces vivos dentro del sector pesquero de Kenia

RESUMEN. Los peces vivos tienen una gran demanda en todo el mundo, especialmente en China, donde los estándares de calidad se alinean con las preferencias de los consumidores. En Kenia, los debates sobre peces vivos, particularmente en regiones ricas en acuicultura, son puntos focales. Sin embargo, la falta de un enfoque sistemático para el transporte de peces vivos plantea desafíos para las partes interesadas. Esta investigación explora las actitudes y percepciones de las partes interesadas en

Kenia con respecto a la adopción del transporte de peces vivos, arrojando luz sobre los procedimientos de transporte y los desafíos del sector. Utilizando un diseño de investigación descriptivo, se recopilaron datos primarios de diversos actores de la acuicultura a través de un cuestionario, abordando sus conocimientos, percepciones y actitudes hacia el transporte de peces vivos en el país. El estudio revela patrones variados en Kenia, influenciados por el propósito y la distancia. Los coches privados ocupan un lugar destacado con 26,3%, con Nyanza y Mombasa a la cabeza con 35%. Las furgonetas modificadas prevalecen en las regiones Central-Nairobi y Occidental (25% y 22,5%, respectivamente), mientras que el transporte público está muy extendido, especialmente en Central y Nairobi (25%). Los vehículos para peces vivos construidos expresamente dominan en Western y Nyanza (20% y 17,5%, respectivamente). Los crustáceos como langostas y cangrejos se exportan principalmente desde la región Costa (27,5%). En general, los participantes evaluaron su conocimiento sobre el transporte de peces vivos como moderado, con una comprensión básica del bienestar de los peces. Los comentarios indican prácticas comunes en el transporte de peces vivos en Kenia, como tanques sellados, bolsas de plástico y vehículos especialmente diseñados. Las fluctuaciones de temperatura y oxígeno plantean un desafío importante durante el transporte en todas las regiones, particularmente en Mombasa y Kisumu. El uso de anestésicos, especialmente para el consumo de pescado, es poco frecuente. El estudio reveló percepciones favorables de las partes interesadas sobre el transporte y el bienestar de los peces vivos, lo que indica una adopción temprana. Se recomienda realizar investigaciones adicionales sobre el bienestar de los peces, las mejores prácticas de gestión, los avances tecnológicos y los estudios interdisciplinarios para mejorar la sostenibilidad del sector del transporte de peces vivos y el bienestar de los peces en Kenia.

Palabras clave: Transporte vivo, acuicultura, calidad del agua, bienestar de los peces, actitudes y percepciones públicas.

INTRODUCTION

Fish, a longstanding affordable protein source for rural communities globally, has witnessed a consistent rise in consumption according to FAO (2022). As aquaculture production expands, concerns about the welfare of farmed fish have garnered attention globally and in Kenya, extending to consumers, animal protection activists, researchers, and intensive fish farmers (Garrett et al. 1997). Live fish transportation, a common practice in aquaculture, is primarily done by road, but it poses potential adverse effects on fish well-being (Peer Mohamed and Devaraj 1997; Prasad et al. 2020; Nair et al. 2023).

In Kenya, live fish are regularly transported from hatcheries to farms or mature fish to markets for further growth as broodstock or sale, respectively. Two main water-based transportation methods are employed by fish farmers. The first involves water-filled containers with an external oxygen source, such as oxygen tanks, while the second uses sealed plastic bags filled with oxygen before transporting fingerlings or broodstock. This closed system is prevalent in Asian countries like China and India (Berka 1986; Muzaddadi et al. 2017; Nair et al. 2023). Despite aquaculture systems being species-specific and localised, the transportation of live fish is essential for growing and expanding aquaculture farms. Road transport, as observed in Australian salmonid production, is prevalent, especially in Tasmanian Atlantic salmon culture, involving the transport of juvenile live fish from inland freshwater hatcheries to coastal marine farms for further growth and eventual slaughter (King 2009).

Live fish transport encompasses pre-transport procedures, procedures during transport, and post-transport processes. Strenuous procedural steps, if not handled properly, can potentially stress fish. The use of salt during transportation is recommended, especially for air-breathing pirarucu fingerlings, to reduce stressors during long-distance transportation (Iversen et al. 1998; Gomes et al. 2006). Common stressors include improper handling, air exposure, inadequate food utilisation, poor conditioning, stomach evacuation before transportation, poor water quality, and inappropriate packaging densities concerning oxygen availability in the bags (Harmon 2009; Saeed et al. 2022; Zhang et al. 2022). Sudden changes in water temperature and rapid water movement have also been identified as emerging stressors for fish during transportation (Pakhira et al. 2015).

Maintaining the health and well-being of live fish during transportation is particularly challenging, especially over long distances and with larger fish. Overstocking of larger fingerlings beyond optimal oxygen levels in packaging bags has resulted in significant fingerling mortality for Nile tilapia (*Oreochromis niloticus*) farmers in Kenya (Munguti et al. 2022). Physiological responses such as erratic movements in fish during transportation have been reported, indicating stress that elevates glucocorticoids such as cortisol levels and blood glucose content (Manuel et al. 2014). Excessive physiological stress diminishes fish vitality and increases mortality, as observed in African catfish (*Clarias gariepinus*) during overland transportation (Dawo et al. 2023).

Kenya has ventured into the export of live fish and crustaceans, including crabs and lobsters, to China, an important global consumer (MoALF 2023). Inland aquaculture, particularly freshwater farming of finfish like Nile tilapia, African catfish and trout (*Oncorhynchus mykiss*), constitutes over 80% of Kenya's total aquaculture production in 2021 (Munguti et al. 2022). Modern aquaculture methods involving live fish fingerlings, such as probiotics in tilapia fish farming and biofloc, are being adopted (de Araújo et al. 2018 and Ntakirutimana et al. 2023). Fish farms are concentrated in western regions and Nyanza, with the central part of Kenya experiencing a rise in aquaculture adoption due to the government's 'Eat More Fish' campaign. Cage fish farming, supported by the Aquaculture Business Development Program in Lake Victoria regions, has gained traction. However, the proliferation of unregulated, illegal fish cages along the shoreline of Lake Victoria is considered a looming economically and environmentally disaster (Njiru et al. 2019; Syanya et al. 2024). New cage farming technologies have increased the necessity for live fish transportation to restock and supply the growing number of cages along Lake Victoria. Ensuring a life-support system, including oxygenation for respiration, is crucial when transporting live fish by road, as pH needs to be controlled on longer journeys (Shabani et al. 2016).

In Nairobi, Kenya, Chinese hotels buy live fish believing it is healthier and more flavourful than previously slaughtered or preserved fish. Challenges in meeting health, quality, and animal welfare standards arise in the transportation and sale of live fish. Mortality of transported live fish has been a significant concern for global aquaculture, leading to companies such as Victory Farms in Kenya to use refrigerated vans to transport fish. Approximately, 7% of annually transported live fish end up as dead fish, often linked to transport duration and inappropriate procedures (Park and Lim 2014; Muzaddadi et al. 2017; Nair et al. 2023).

Reviews on fish transport often lack a connection to welfare issues, and unlike livestock production, stakeholders in the fish industry are not explicitly responsible for fish welfare. There is a crucial need to educate and disseminate information related to live fish transportation handling and welfare among fisheries and aquaculture stakeholders. The study therefore aimed to comprehensively understand live fish transportation in Kenya, focusing on current practices, fish farmers' attitudes and perceptions. Through this, the study sought to identify key insights contributing to improving the overall welfare and efficiency of live fish transport within the Kenyan aquaculture industry. This information will highlight perceived and potential fish welfare issues, guiding future research in Kenya's fisheries sector.

MATERIALS AND METHODS

In this research, a questionnaire was administered to stakeholders in Kenyan fisheries and aquaculture industry through Kobo data collection tools. The lead researcher supervised this process in five distinct regions across the country. Stakeholders in these areas were actively involved in the live fish transportation business, supplying fish markets,

aqua shops, fish farms and so on in all the country. The study area covered the western, Nyanza, Coast, Central, and Nairobi former provisional regions. The research employed a convergent research design. In this design, both qualitative and quantitative data were collected simultaneously but analysed separately. Results from both methods were then compared and interpreted to reach a conclusion. The purposive sampling technique was utilized to identify potential participants who were adults working in Kenyan fisheries and aquaculture industry and actively engaged in live fish fishery-related roles for at least one year. A total of 80 participants were selected, 20 from each region. This sample size was determined based on previous literature, which suggested that for qualitative research methods, an appropriate sample size might range from 5 to 50 participants, which is a recognized standard for determining sample size (Knight and Barnett 2008; O'Brien et al. 2014). Qualitative data obtained from open-ended questionnaires were transcribed and coded based on the predefined categories derived from the research questions. Thematic analysis was subsequently conducted to examine and interpret the underlying themes related to live fish transportation across different regions in the country. This process facilitated the identification of patterns and offered valuable insights into participants' perspectives. On the other hand, quantitative data gathered from the questionnaires was analysed using descriptive statistics, encompassing a cross-tabulation, frequencies, means and percentages. This analysis was performed using SPSS software version 24V. Additionally, inferential statistics were employed, including t-tests and Chi-square tests, depending on the nature of the research questions. These statistical tools were utilized to examine relationships and differences within the dataset reported by respondents regarding live fish transportation. The dual approach of qualitative and quantitative analyses allowed for a comprehensive exploration of the research topic, combining the richness of participants' perspectives with the numerical precision derived from statistical methods.

RESULTS

Demographic data of the respondents associated with live fish transportation

The study reveals diverse experiences in aquaculture and fisheries-related activities among participants in Kenya engaged in live fish transport business. Females engaged in live fish transportation predominantly aged between 49 to 58 and above 59 years, while most males involved were aged 39 to 40, 29 to 38, 18 to 28, and 49 to 58 years old. Residential patterns showed that individuals aged 49 to 58, mainly residing in urban areas, exhibited a distinct trend compared to other age groups. Youth aged (18-28) played managerial roles in live fish transportation, while those aged 29-38 years were mainly involved in transportation with no managerial responsibilities. Participants aged 39-48 focused on fish wholesaling and aquaculture facilitation. Those aged 49-58 years engaged in fish farming, retailing, and transportation, while those above 59 years were predominantly in fish retailing and seafood restaurant ownership. The findings reveal specialization, a trend of youth leadership in transportation, and expertise associated with specific age groups in distinct roles within the fisheries industry (Figure 1).

Live fish transport process

Mode of transport and methods of live fish packaging

Drawing from the study's results on live fish transportation, respondents revealed a variety of modes and types of transport. Private cars emerged as the dominant mode, constituting 26.3% across regions, notably led by Nyanza and Mombasa at 35%. Varied vehicle sizes and volumes were identified, reflecting purpose and distance considerations. Modified vans were prevalent in Central, Nairobi, and Western regions (25% and 22.5%).

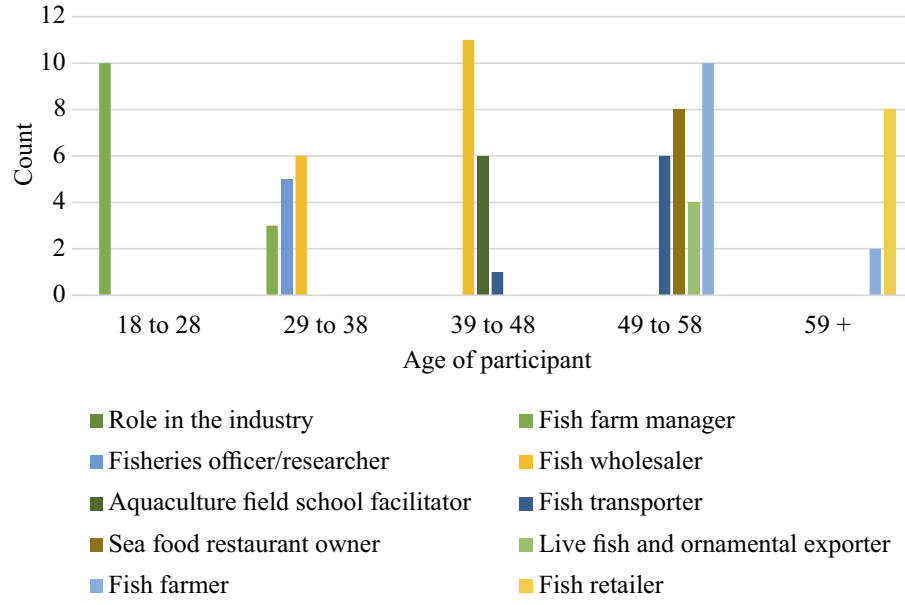

Figure 1. Role of participants in the live fish transport sector in Kenya based on their age.

Public transport featured in all regions, with Central and Nairobi leading at 25%. Purpose-built vehicles were prominent in Western and Nyanza (20% and 17.5%). Notably, modified trucks were least used, reported at 17.5% and 13.7% in Nyanza and Coastal regions. Respondents highlighted the adaptability of private cars for small fish volumes in research transport, while modified trucks were favoured for larger volumes (Table 1).

In relation to live fish transportation methods, respondents outlined diverse approaches. Polyvinyl chloride (PVC) open tanks, foam and cooler boxes, and aerated bags emerged as commonly utilized means. PVC transport tanks were prominent for transporting large fish volumes or over extended distances in the Western region (28.8% of respondents). Aerated bags were widely employed in Western (28.8%), Nyanza (37.5%), and Central (30%) regions. Modified vehicles, homemade baskets with sealed plastic bags, and ice found use in the Coastal and Western regions (20% and 12.5% of respondents, respectively). Urban areas in Central, Nairobi, and the Coastal region favoured foam and cooler boxes (31.3% and 30%). Aerated bags were prevalent for short-distance deliveries in Western, Nyanza, Central, and Nairobi regions. Trucks with PVC tanks were deemed essential for large-scale transport, especially for broodstock and larger fish, notably in the Western and Coastal regions (28.85% and 21.3% of respondents, respectively) (Figure 2).

Live fish species handled and transportation destinations

Participants had varied experiences in their roles. Those in aquaculture research, fish farming, and hatchery management worked not only with commonly farmed species like tilapia and catfish but also with local species such as trout and carp (*Cyprinus carpio*), especially in the Central and Nairobi regions. Commonly transported species included tilapia fingerlings, broodstock, ornamental fishes, and catfish, reported across nearly all regions. Nyanza and the Western region excelled in handling tilapia fingerlings and broodstock (32.5% of respondents in each region) (Table 2). Ornamental fishes such as guppy (*Poecilia reticulata*), zebraf-

Table 1. Percentage distribution of the mode and method of live fish transport in Kenya.

Mode and method of live fish transportation	Distribution per region			
	Western region	Nyanza region	Central and Nairobi region	Coastal region
Live fish purpose-build veicles	20.0	17.5	12.4	13.8
Modified vans	22.5	15.0	25.0	17.5
Private cars	26.3	35.0	26.3	35.0
Modified tracks/lorries	11.2	17.5	11.3	13.7
Public transport means	20.0	15.0	25.0	20.0
Total (%)	100.0	100.0	100.0	100.0

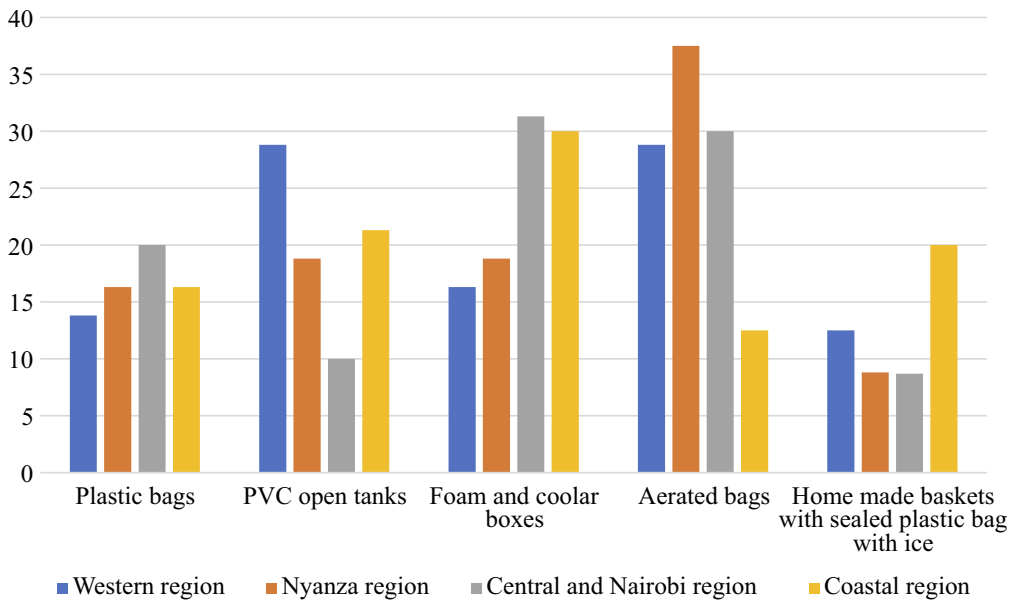

Figure 2. Distribution of methods for live fish packaging during transportation per region in Kenya.

ish (*Danio rerio*) and goldfish (*Carassius auratus*) were predominantly transported in major regions with cities, i.e. Central and Nairobi, Coastal, and Nyanza, reported by 25%, 22.5%, and 21.5% of respondents, respectively. Trout and carp were exclusively transported in Central and Nairobi (25% of respondents). Crustaceans, such as lobsters and crabs, were transported primarily for exportation mainly in the Coastal region and Central-Nairobi regions (27.5% and 8.8% of respondents, respectively). Mature tilapia and catfish were transported to major hotels in the Western and Nyanza regions (21.3% and 18.8%, respectively) (Table 3). Besides freshwater fish, respondents also worked with

Table 2. Percentage of fish species handled during live fish transportation in Kenya.

Fish species	Distribution per region			
	Western region	Nyanza region	Central and Nairobi region	Coastal region
Tilapia fingerlings and broodstock	32.5	32.5	20.0	13.8
Catfish fingerlings and broodstock	16.3	12.5	10.0	7.5
Ornamental fishes	20.0	21.5	25.0	22.5
Grown out tilapia and catfish	21.3	18.8	6.3	3.8
Trout and carp	0.0	0.0	25.0	0.0
Crabs and lobsters	0.0	0.0	8.8	27.5
Other fish species	10.0	15.0	5.0	25.0
Total (%)	100.0	100.0	100.0	100.0

other species, including marine fish and shellfish in the Coastal region (25% of respondents), lungfish (*Protopterus ethiopicus*) and Nile perch (*Lates niloticus*) in the Nyanza region (15% of respondents), and mudfish (*Clarias anguillaris*), reported as one of the most popular other fish species in the Western region (10% of respondents).

Participants were asked about typical destinations for transported live fish and their locations. They cited wholesale markets, supermarkets, wet markets, laboratories, restaurants, residential communities, and private residences as popular destinations. Fish farms were the predominant destinations in the Western and Nyanza regions, reported by 36.3% and 31.3% of respondents, respectively, due to the high demand for fingerlings to stock ponds while they are alive and in good conditions. Live fish exports to other countries were majorly reported in the Coastal region (28.8% of respondents) and Central and Nairobi regions (18.8% of respondents). Low-live fish export cases were reported in the Western and Nyanza regions (2.5% and 6.3% of respondents, respectively). Live fish aqua shops and residential areas and villages were target markets, mainly in Nyanza, Western, Central, and Nairobi regions (20%, 16.3%, and 12.5% of respondents, respectively). However, the Coastal region recorded the least live fish aqua shops and residential areas as destinations for live fish. Furthermore, hotels and restaurants were reported as common destinations for grown-out and mature fishes of different species in the Coastal region (38.8%), Central and Nairobi region (35%), and Nyanza region (28.8%) of respondents. The Western region reported the least hotels and restaurants as destination for live fish species (20%) (Table 3).

Fish wholesale markets were also identified as target marketplaces for live fish, with high numbers witnessed in Western and Nyanza regions, both at 13.8% of respondents. Central and Nairobi and Coastal regions equally had fish wholesale markets that purchase live fish (12.5%) (Table 3). Respondents in Western, Central, and Coastal regions mentioned transporting fish from lakes, rivers, and reservoir areas to laboratories for experimental purposes (Western at 11.3%, and Coastal and Central both at 7.5% of respondents). Additionally, fish were transported to various institutions of higher learning such as universities, fisheries research centres, and polytechnic laboratories for experiments.

Table 3. Percentage of live fish transportation destinations in Kenya.

Live fish transport destination	Distribution per region			
	Western region	Nyanza region	Central and Nairobi region	Coastal region
Fish wholesale markets	13.8	13.8	12.5	12.5
Hotels and restaurant	20.0	28.8	35.0	38.8
Institutional laboratories	11.3	0	7.5	7.5
Fish farms	36.3	31.3	13.8	6.3
Live fish aqua shop and village areas	16.3	20.0	12.5	6.3
Export to other countries	2.5	6.3	18.8	28.8
Total (%)	100.0	100.0	100.0	100.0

Knowledge and perception of live transport and use of fish anaesthetics

Participants rated their knowledge and perception of live fish transportation on a four-point scale. In the Western region, 56.3% had Moderate knowledge and Low perception, while 22.5% had Low knowledge and Poor perception. Conversely, in Nyanza, 37.5% reported High knowledge and perception, followed by 28.8% with Moderate knowledge. Central and Nairobi stood out with 53.8% reporting Very High knowledge and perception, while 23.8% had High knowledge and perception, 12.5% Moderate knowledge and Low perception, and 10% Low knowledge and Poor perception. In the Coastal region, 40% reported High knowledge and perception, 22.5% Moderate knowledge and Low perception, 18.8% Very High knowledge and perception, and 18.8% Low knowledge and Poor perception (Figure 3).

The study identified patterns in the use of chemical anaesthetics in live fish transport, finding their absence in food fish transportation but prevalence in research-related transportation, particularly in the Central-Nairobi (30%) and Nyanza (20%) regions. Fish species with national protection status, sensitive to stress, were the primary recipients of anaesthetics during transport. In the Western and Nyanza regions, alternative methods like ice were extensively employed (75% and 67.5%, respectively), with Coastal, Central, and Nairobi regions also reporting ice use (40% and 45%) (Figure 4). Sea salts, especially in high concentrations, played a role in water quality control during transport, notably in the Coastal region (36.3%), while minimal use was reported in Western, Nyanza, and Central-Nairobi regions. Vitamin C functioned similarly, with higher usage in the Central-Nairobi region (21.3%), followed by Coastal and Nyanza regions (13.8% and 10%). Anaesthetics were applied to slippery to handle fish species like Catfish (*C. gariepinus*) and lungfish (*P. ethiopicus*) in the Western and Nyanza regions, while in the Coastal region, marine species and crustaceans used anaesthesia due to their spines and carapace shape, albeit in low concentrations.

Challenges during live transport and handling

Participants identified several challenges in live fish transportation, including water temperature control, oxygen level fluctuations, water quality,

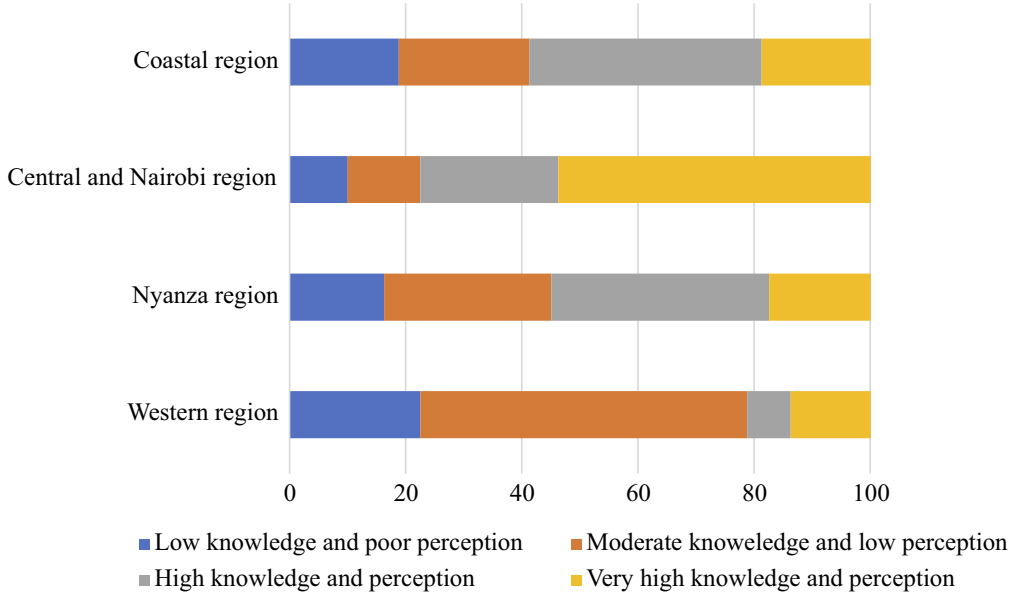

Figure 3. Perception and knowledge of live fish transportation in Kenya.

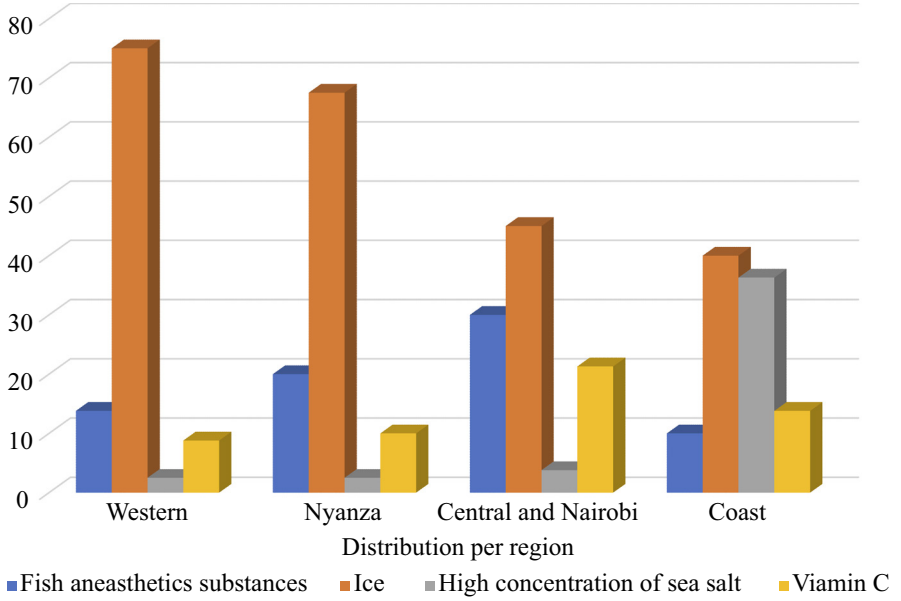

Figure 4. Use of fish anaesthetics and other chemicals for live fish transportation per region in Kenya.

vehicle vibration, transport density, fish species, and transportation time. Oxygen level fluctuation emerged as the primary concern across all regions, notably in Nyanza (32.5%) and Central-Nairobi (28.8%). In the Western region, stakeholders highlighted transportation time (22.5%), water temperature control (18.8%), and vehicle vibration and transport density (12.5%) as significant challenges.

Nyanza reported transportation time (25%) and water quality (20%) as major issues. In Central-Nairobi, in addition to oxygen level fluctuations, vehicle vibration (25%) and water temperature control (17.5%) were problematic. The Western region faced oxygen fluctuation (23.8%) as a major challenge, while Nyanza grappled with transportation time (25%) and water quality (32.5%). The Coastal region identified water temperature control (40%) as a major challenge. In Central-Nairobi, oxygen level fluctuations (28.8%) and vehicle vibration and transport density (25%) were prominent challenges. Interestingly, fish species biodiversity posed the least problem in live fish transportation across all regions (Figure 5).

DISCUSSION

This study provides insights into live fish transportation practices in fisheries and aquaculture sectors in Kenya. Demographic diversity highlights, with older, experienced females dominating the activity. This aligns with results from Ndanga et al. (2013) and Calhoun et al. (2016), which show the participation of women in aquaculture. On the other hand, several male groups, especially youth, participate in fish farming, research and extension functions, in line with the research of Wamukota (2010) and Syanya and Mathia (2023), who highlight gender disparities in Kenyan aquaculture. The study further reveals a notable contrast in residential choices of participants. Older individuals tend to prefer urban settings, while the youth predominantly reside in rural areas. This interplay of age, gender, and location underscores the complex dynamics shaping the participation in the live fish transportation industry. Interestingly, this contradicts the findings from Munguti et al. (2014), who highlighted older people in fish farming residing in rural areas. Kimani et al. (2020) and Munguti et al. (2022) also reported diverse roles played by participants based on age, emphasizing the multifaceted nature of aquaculture and fisheries-related occupations and urging targeted strategies for addressing

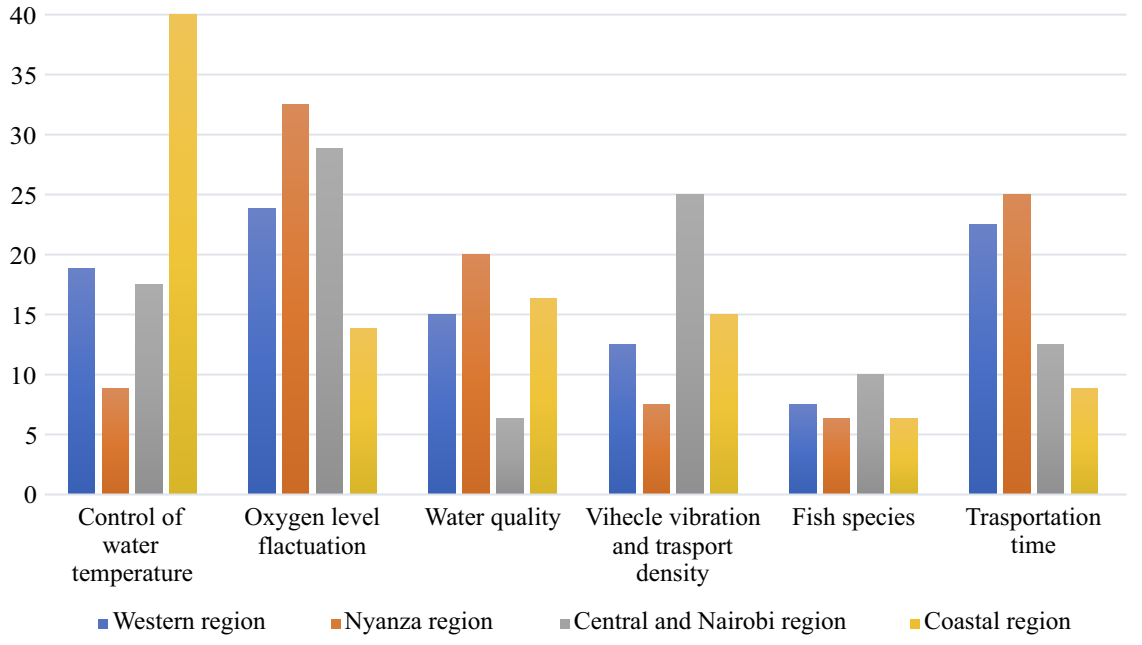

Figure 5. Challenges faced during live fish transportation in Kenya.

the unique challenges faced by different participant groups globally in the live fish transportation sector.

Results also align with existing literature, highlighting the significance of understanding demographics and roles in live fish transportation for effective policy formulation and sustainable aquaculture development (Waithanji et al. 2020; Niyibizi et al. 2022). The interconnection between demographic factors and roles in the fisheries sector is crucial for optimizing interventions and promoting resilience in the live fish transportation sub-sector in Kenya and globally. Various modes and methods of transporting live fish in Kenya reflect the nuanced nature of the industry based on factors such as purpose, distance and characteristics of fish. Private cars have become as the predominant option nationwide, in line with the findings of Lekang (2019), Devkota et al. (2023) and Nair et al. (2023) in India. Respondents in the Western and Central regions report regular use of private cars, while in Nyanza and Mombasa there is a higher prevalence, indicating the accessibility and availability of private cars for transporting fish from farms. Harmon (2009) also emphasized the use of smaller vehicles to reduce stress and transportation costs during live fish transportation. This study also reveals the need for robust regulatory measures, especially for modified private cars, ensuring compliance with health and safety standards during live fish transportation. Recognizing private automobiles as a prominent mode of transportation coincides with the practicality of their use on inaccessible routes, pointing out the importance of adapting regulatory frameworks to diverse practices, and promoting a safe and efficient live fish transportation system to minimize mortality of fish during transit (Jia et al. 2016).

Respondents indicated that modified vans play a vital role in live fish transportation in Central, Nairobi, and Western Kenya, as suggested by Nair et al. (2023). Notably, public transport is a noteworthy aspect in Central and Nairobi, showcasing the adaptability within the industry, a trend similarly observed by Asiedu et al. (2023) in Ghana. In Western and Nyanza regions, purpose-built vehicles are commonly used, as also observed Peer Mohamed and Devaraj (1997) and Zhang et al. (2022). This highlights its importance in enhancing fish survival and reducing stress during transportation. The stress associated with public road transport (Manuel et al. 2014), stands in contrast to the findings of Stieglitz et al. (2012), who reported significant survival rates for juvenile cobia transported under variable salinity levels during shipment.

The adoption of private cars and purpose-built vehicles in Kenya for research underscores the need for tailored solutions in the fisheries and aquaculture sectors. Vanderzwalmen et al. (2021) noted their common use in commercial live fish transportation worldwide. Aerated bags are prevalent for short-distance deliveries, reflecting widespread fish farming activities and addressing fingerling mortality concerns. Wang et al. (2020) emphasized well-aerated packaging for Chinese-farmed sturgeon transport. Region-specific strategies are crucial for optimizing live fish transportation, with PVC tanks favoured for large-scale transport, aligning with Harmon (2009), Pramod et al. (2010), and Treasurer (2010), ensuring optimal conditions during transit, especially for broodstock and larger fish.

Live fish packaging is vital for fish survival during transit. Different methods are employed in Kenya to package and transport live fish, including PVC tanks for long-distance transport, prevalent in Western Kenya (Shabani et al. 2016; Yang et al. 2021). Conversely, aerated bags are prefered in Nyanza, Central, and Nairobi, especially for fingerlings. Erikson et al. (2022) found that closed systems enhance water quality and reduce stress. Singh et al. (2004) and Wang et al. (2020) reported stress-appropriate packaging for fry transportation. These methods ensure the welfare of Indian carps (*Catla catla, Labeo rohita*, and *Cirrhinus mrigala*) during transportation. This was crucial for successful aquaculture practices.

In Kenya, aquaculture research and fish farming involve a diverse range of species, from commonly farmed tilapia and catfish to local species like trout

and carp (Kaliba et al. 2007; Neira et al. 2009; Munguti et al. 2014), showcasing the complexity of the industry. Tilapia fingerlings, broodstock, ornamental fishes, and catfish are commonly transported species across regions, indicating their significance in live fish transportation. Urban markets, particularly in Nairobi, Nyanza and the coastal region, show high demand for ornamental fish, similar to what occurs in Australia (Hood et al. 2019). Crustaceans, primarily from the coastal region, and mature tilapia and catfish for hotels in the Western and Nyanza regions, demonstrate the link between aquaculture and the hospitality sector, similar to practices reported in India and Nepal (Apine et al. 2019; Devkota et al. 2023). Participants also work with diverse freshwater and marine species across different regions, highlighting the richness of the Kenyan fisheries industry.

The diversity of fish species in the aquaculture sector of Kenya (Prabu et al. 2019; Syanya et al. 2023a), accentuate the adaptability of the fisheries industry, a characteristic also observed in the coastal aquaculture of India (Krishnan and Birthal 2002). This study indicates that destinations of live fish are influenced by economic activities and market demands, with a concentration of fish farms noted in the Western and Nyanza regions, consistent with their prominence in aquaculture (Genschick et al. 2021; Otieno et al. 2021). Coastal regions, functioning as international trade hubs, demonstrate high live fish export rates driven by demand for crustaceans such as shrimp, crabs, and prawns (Wamukota 2010). Conversely, lower export rates in Western and Nyanza reflect a focus on local markets and subsistence farming (Otieno et al. 2021).

Preferences for live fish stores and residential areas as target markets in Nyanza, Western, Central, and Nairobi regions, suggests growing local consumer demand for direct purchases. The Central region, highly embracing fish farming, focuses on major hotels and restaurants as markets for their increased fish production, offering either fresh or live fish. The coastal region, which emphasizes export-oriented markets, relies less on live fish shops (Wamukota 2010) and more on marine fish marketing in the Malindi coastal regions, where live lobsters and crabs go to international market. Hotels and restaurants in the Coastal, Central and Nairobi regions demand high quality seafood for the tourism and hospitality industries. The Western region has limited involvement with hotels and restaurants due to a distinct regional economic focus. The identification of important wholesale fish markets in Western and Nyanza, reflects their role in supplying live fish to wider markets. Deng (2020) studied the factors affecting fishery production in Ethiopia, and also emphasized the importance of wholesale and retail stores in regions with intensive fish farming and high production. Additionally, the transportation of fish from natural water bodies to laboratories in Western, Central, and Coastal regions, underscores their significance in fisheries research and development.

Results on the knowledge and perception of live transport and use of fish anaesthetics in Kenya, reveals variations in fisheries awareness and understanding of stakeholders on live fish transportation across regions. In the Western region, where fish farming is prevalent, they showed moderate knowledge and low perception, possibly due to practical experience but limited theoretical knowledge. This fact aligns with the findings of Yang et al. (2021), were a high level of perception, extensive knowledge, and positive attitudes was reported among stakeholders in the live fish transportation sector within the aquaculture industry in China. In contrast, Nyanza region, with significant fisheries activities along Lake Victoria, had reasonable participant responses with high knowledge and perception, reflecting a more comprehensive understanding of the value of consuming live fish directly from the lake. The variability, including respondents with very high knowledge and perception in live fish transport, suggests a diverse participant background in aquaculture and capture fisheries, as pointed out by Njiru et al. (2019), Aura et al. (2020) and Syanya et al. (2024). In the Central and Nairobi regions, the majority of participants exhibit

very high knowledge and perception of live fish transportation, attributed to centralized academic and research institutions in urban areas. Similar concerns about frozen-farmed fish quality prompting a shift to live fish consumption were noted by Syanya and Mathia (2023). Conversely, in the Coastal region, majority of participants reported high knowledge and perception due to its focus on marine fisheries. Variances in attitudes towards live fish transportation align with factors like gender, education, and access to resources in China (Jiang et al. 2023). Disparities in the use of anaesthetics, primarily in Central/ Nairobi and Nyanza regions, with comparatively higher response rate on this matter, were aimed to protect stress during fish transportation, contrasting with the preference for ice as transportation method in the Western/Nyanza region. Regional variations in preferred techniques are influenced by factors such as resource availability and local practices. Results from Nair et al. (2023) also indicated that availability of resources determined the nature of coolant used for live fish transportation in India. These findings elaborate on the importance of region-specific strategies to enhance understanding and awareness of live fish transportation practices and the use of anaesthetics in the Kenyan fisheries sector.

Findings revealed that different methods are employed to control water quality during live fish transportation, with sea salts being predominantly used in the Coastal region, probably due to its effectiveness in maintaining water parameters suitable for marine species (Gomes et al. 2006). Conversely, the preference for vitamin C in the Central/ Nairobi and Coastal regions may stem from its known benefits in reducing transport stress, as supported by Harmon (2009) and Yang et al. (2021). The minimal usage of sea salts and vitamin C in the Western/Nyanza regions could be attributed to regional preferences or availability of alternative methods. Additionally, tailored anaesthetic use for specific species in Western/Nyanza and the Coastal region highlights a nuanced approach to ensure the welfare of live fish during transportation, considering species characteristics and regional preferences, as advocated by Farrell et al. (2010), Franks et al. (2021), and Yang et al. (2021). These findings emphasises on the importance of considering both species-specific needs and regional factors in developing effective water quality control methods for live fish transportation.

Harmon (2009) also noted the importance of minimizing stressors during live fish transportation to ensure their survival and well-being. This study identifies regional challenges in live fish transportation, including oxygen level fluctuations, transportation time, water temperature control, and vehicle vibration. Nyanza, Central, and Nairobi regions face oxygen management issues, possibly due to logistical shortcomings. The Western region grapples with transportation time and vehicle vibration, likely influenced by poor roads and infrastructure. A similar finding was noted by Zhang et al. (2022), where they addressed the oxygen concern in waterless live fish transportation by creating a model using the IPSO-GRU method. This model offers effective prediction and early-warning functions for oxygen consumption during fish waterless keep-alive transportation. In Nyanza, emphasis on transportation time and water quality highlights potential shortcomings in duration and water conditions maintenance, possibly due to the regional focus on fresh fish transportation rather than live fish. This contradicts results from Muzaddadi et al. (2017), who noted the role of live fish transportation in enhancing value and commanding higher market prices in India, where live table carp were priced at 1.44-2.40 USD kg^{-1}, while dead and iced fish were priced below 1.20 USD kg^{-1}. This is an indication that live fish tend to fetch higher prices at local and international markets, highlighting a market preference for live fish over iced or dead fish. These results illustrate the complex interplay of environmental, logistical, and market factors influencing live fish transportation challenges and strategies. Yang et al. (2021) also reported similar challenges in China, emphasizing the universal nature of these issues across different regions of the world.

Challenges faced in the Central and Nairobi regions, including oxygen level fluctuations, vehicle vibrations, and water temperature control, are likely influenced by the urban-centric nature of these areas, where transportation logistics and environmental factors are significant. This aligns with similar findings in Nepal and China, regarding live fish transportation challenges (Yang et al. 2021; Devkota et al. 2023). The struggle in coastal regions to control transport water temperature is a reflection of their warm climate, which requires specialized measures for optimal transport conditions. The minimal concern for biodiversity challenges of fish species in all regions, suggests competition among stakeholders over the management of various fish species during transport, consistent with findings by Jia et al. (2016) and Yang et al. (2021) in China. These multifaceted challenges are influenced by regional characteristics, transportation logistics, and varying approaches among live fish stakeholders. Thus, region-specific strategies are crucial for addressing the specific challenges encountered in Kenya's live fish transportation industry.

CONCLUSIONS

This study sheds light on stakeholders' perceptions and attitudes toward the transportation of live fish and animal welfare. Although positive attitudes prevail among various stakeholders in the fisheries sector regarding the transportation and consumption of live fish in the country, full adoption is still in its early stages. This warrants further research on key fish welfare issues across capture fisheries, as well as aquaculture stakeholders' attitudes on a larger scale during the live fish handling process. It is recommended to develop best management practices and guidelines for live fish transportation, including the incorporation of educational initiatives, such as training on fish quality and assurance for stakeholders in the fisheries sector. Additionally, it is suggested to explore and adopt technological advancements in live fish handling and transportation that align with the current live fish market and practices in developed countries such as China and India. Researching fish anaesthetics for food fish and tailoring interventions regionally in Kenya are also proposed.

The focus of these recommendations is on fish welfare initiatives, involving diverse fisheries stakeholders, fisheries policymakers, longitudinal studies, and fostering interdisciplinary research. The goal is to enhance live fish transportation practices, ensuring sustainability and the well-being of the fish.

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Conflict of interest

All authors have read and agreed to the draft version of the manuscript, and there is no conflict of interest among them.

Data availability statement

The paper and its supporting information files contain all necessary data.

Author contributions

Fredrick Juma Syanya: conceptualization, writing original draft. Wilson M. Mathia: data curation, review, editing. Paul Mumina: writing original draft, data curation, review, editing. Joel A. Litabas: conceptualization, methodology, project administration, data collection. Caleb Sifuna: methodology, project administration, data collection.

REFERENCES

Apine E, Turner LM, Rodwell LD, Bhatta R. 2019. The application of the sustainable livelihood approach to small scale-fisheries: the case of mud crab Scylla serrata in South west India. Ocean Coast Manage. 170: 17-28. DOI: https://doi.org/10.1016/j.ocecoaman.2018.12.024

Asiedu B, Failler P, Amponsah SKK, Okpei P. 2023. Fishers' lives matter: social issues in small-scale fisheries migration of Ghana. Mar Fish Sci. 36 (2): 119-135. DOI: https://doi.org/10.47193/mafis.3622023010503

Aura CM, Nyamweya CS, Owili M, Gichuru N, Kundu R, Njiru JM, Ntiba MJ. 2020. Checking the pulse of the major commercial fisheries of lake Victoria Kenya, for sustainable management. Fish Manage Ecol. 27 (4): 314-324. DOI: https://doi.org/10.1111/FME.12414

Ball EE, Goode KJ, Weber MJ. 2020. Effects of transport duration and water quality on age-0 walleye stress and survival. N Am J Aquacult. 82 (1): 33-42. DOI: https://doi.org/10.1002/NAAQ.10114

Berka R. 1986. The transport of live fish. A review. EIFAC Technical Papers. 48. 52 p.

Calhoun S, Conway F, Russell S. 2016. Acknowledging the voice of women: implications for fisheries management and policy. Mar Policy. 74: 292-299. DOI: https://doi.org/10.1016/j.marpol.2016.04.033

Dawo AB, Salosso Y, Pasaribu W, Studi P, Perairan B, Kelautan P, Perikanan D. 2023. Inventarisation of parasites in catfish (*Clarias* sp.) and tilapia (*Oreochromis niloticus*) in the regency of North Central Timor. J Fish Mar Res. 7 (1): 22-29. DOI: https://doi.org/10.21776/UB.JFMR.2023.007.01.3

de Araújo ERL, Barbas LAL, Ishikawa CM, de Carla Dias D, Sussel FR, de Almeida Marques HL, Tachibana L. 2018. Prebiotic, probiotic, and symbiotic in the diet of Nile tilapia post-larvae during the sex reversal phase. Aquacult Int. DOI: https://doi.org/10.1007/s10499-017-0201-7

Deng GT. 2020. Assessment of factors affecting fish production and marketing in Gambella Region, Ethiopia. Sci World J. DOI: https://doi.org/10.1155/2020/5260693

Devkota H, Jha DK, Joshi TP, Shrestha S, Bhandari MP, Poudel N. 2023. Exploration of sustainable live fish business in Nepal. J Agric Environ. 24: 137-148. DOI: https://doi.org/10.3126/AEJ.V24I01.58180

Erikson U, Rosten C, Klebert P, Aspaas S, Rosten T. 2022. Live transport of Atlantic salmon in open and closed systems: Water quality, stress and recovery. Aquacult Res. 53 (11): 3913-3926. DOI: https://doi.org/10.1111/ARE.15895

[FAO] Food and Agriculture Organization of the United Nations. 2022. The state of the world fisheries and aquaculture. Towards blue transformation. Rome: FAO. DOI: https://doi.org/10.4060/cc0461en

Farrell AP, Tang S, Nomura M, Brauner CJ. 2010. Toward improved public confidence in farmed fish: a Canadian perspective on fish welfare during marine transport. J World Aquacult Soc. 41 (2): 225-239. DOI: https://doi.org/10.1111/J.1749-7345.2010.00350.X

Franks B, Ewell C, Jacquet J. 2021. Animal welfare risks of global aquaculture. Sci Adv. 7 (14): eabg0677. DOI: https://doi.org/10.1126/sciadv.abg0677

Garrett ES, Lima Dos Santos C, Jahncke ML. 1997. Public, animal, and environmental health

implications of aquaculture. Emerg Infect Dis. 3 (4): 453-457.

Genschick S, Mekkawy W, Rossignoli C, Benzie JAH. 2021. Growth performance of three strains of Nile tilapia (*Oreochromis niloticus*) on four different feeds in Western and Central Kenya. Aquacult Rep. 20, 100701. DOI: https://doi.org/10.1016/J.AQREP.2021.100701

Gomes LC, Chagas EC, Brinn RP, Roubach R, Coppati CE, Baldisserotto B. 2006. Use of salt during transportation of air breathing pirarucu juveniles (*Arapaima gigas*) in plastic bags. Aquaculture. 256 (1-4): 521-528. DOI: https://doi.org/10.1016/j.aquaculture.2006.02.004

Harmon TS. 2009. Methods for reducing stressors and maintaining water quality associated with live fish transport in tanks: a review of the basics. Rev Aquacult. 1 (1): 58-66. DOI: https://doi.org/10.1111/J.1753-5131.2008.01003.X

Hood Y, Sadler J, Poldy J, Starkey CS, Robinson AP. 2019. Biosecurity system reforms and the development of a risk-based surveillance and pathway analysis system for ornamental fish imported into Australia. Prev Vet Med. 167: 159-168. DOI: https://doi.org/10.1016/j.prevetmed.2018.11.006

Iversen M, Finstad B, Nilssen KJ. 1998. Recovery from loading and transport stress in Atlantic salmon (*Salmo salar* L.) smolts. Aquaculture. 168 (1-4): 387-394. DOI: https://doi.org/10.1016/S0044-8486(98)00364-0

Jia B, St-Hilaire S, Stryhn H, Yu J, Groman DB, Gardner IA. 2016. Analysis of transaction records of live freshwater finfish in China: a case study of customers' claims of fish mortality using cross-classified modeling. Aquacult Rep. 4: 150-155. DOI: https://doi.org/10.1016/J.AQREP.2016.10.003

Jiang B, Tang W, Cui L, Wei Y. 2023. Factors influencing Chinese public attitudes toward farm animal welfare. Front Psychol. 14: 1049530. DOI: https://doi.org/10.3389/fpsyg.2023.1049530

Kaliba AR, Ngugi CC, MacKambo J, Quagrainie KK. 2007. Economic profitability of Nile tilapia (*Oreochromis niloticus* L.) production in Kenya. Aquacult Res. 38 (11): 1129-1136. DOI: https://doi.org/10.1111/J.1365-2109.2007.01772.X

Kimani P, Wamukota A, Manyala JO, Mlewa CM. 2020. Factors influencing financial performance in marine small-scale fisheries value chain in Kenya. Mar Policy. 122. DOI: https://doi.org/10.1016/j.marpol.2020.104218

King HR. 2009. Fish transport in the aquaculture sector: an overview of the road transport of Atlantic salmon in Tasmania. J Vet Behav. 4 (4): 163-168. DOI: https://doi.org/10.1016/J.JVEB.2008.09.034

Knight S, Barnett L. 2008. Justifying attitudes toward animal use: a qualitative study of people's views and beliefs. Anthrozoos. 21 (1): 31-42. DOI: https://doi.org/10.2752/089279308X274047

Krishnan M, Birthal PS. 2002. Aquaculture development in India: an economic overview with special reference to coastal aquaculture. Aquacult Econ Manage. 6 (1-2): 81-96. DOI: https://doi.org/10.1080/13657300209380305

Lekang O. 2019. Transport of live fish. In: Lekang O, editor. Aquaculture engineering. Willey Blackwell. p. 419-430. DOI: https://doi.org/10.1002/9781119489047.CH23

[MoALF] Ministry of Agriculture, Livestock, Fisheries. 2023. Live Fish. (n.d.). [accessed 2023 Dec 7]. https://kilimo.go.ke/live-fish/.

Manuel R, Boerrigter J, Roques J, van der Heul J, van den Bos R, Flik G, van de Vis H. 2014. Stress in African catfish (*Clarias gariepinus*) following overland transportation. Fish Physiol Biochem. 40 (1): 33-44. DOI: https://doi.org/10.1007/S10695-013-9821-7

Mphande J, Hasimuna OJ, Kikamba E, Maulu S, Nawanzi K, Phiri D, Chibesa M, Siankwilimba E, Phiri CJ, Hampuwo BM, et al. 2023. Application of anaesthetics in fish hatcheries to promote broodstock and fish seed welfare in Zambia. Cogent Food Agric. 9 (1). DOI: https://doi.org/10.1080/23311932.2023.2211845

Munguti JM, Kim JD, Ogello EO. 2014. An overview of Kenyan aquaculture: current status, challenges, and opportunities for future development. Fish Aquat Sci. 17 (1): 1-11. DOI: https://doi.org/10.5657/FAS.2014.0001

Munguti JM, Nairuti R, Iteba JO, Obiero KO, Kyule D, Opiyo MA, Abwao J, Kirimi JG, Outa N, Muthoka M, et al. 2022. Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) culture in Kenya: emerging production technologies and socio-economic impacts on local livelihoods. Aquacult Fish Fish. 2 (4): 265-276. DOI: https://doi.org/10.1002/AFF2.58

Muzaddadi AU, Ahmad T, Monika Monika, Nanda SK. (2017). Live table fish transportation - a means of innovative value addition in the fish retail markets of Ludhiana, Punjab. Indian J Fish. 64: 249-253. DOI: https://doi.org/10.21077/IJF.2017.64.special-issue.76296-39

Nair VR, Parvathy U, Jithin TJ, Binsi PK, Ravishankar CN. 2023b. Live transportation of food fishes: current scenario and future prospects. Curr Sci. 124 (4): 418-425.

Ndanga LZB, Quagrainie KK, Dennis JH. 2013. Economically feasible options for increased women participation in Kenyan aquaculture value chain. Aquaculture. (414-415): 183-190. DOI: https://doi.org/10.1016/j.aquaculture.2013.08.012

Neira I, Engle CR, Ngugi C. 2009. Economic and Risk analysis of tilapia production in Kenya. J Applied Aquacult. 21 (2): 73-95. DOI: https://doi.org/10.1080/10454430902892842

Niyibizi L, Vidakovic A, Norman Haldén A, Rukera Tabaro S, Lundh T. 2022. Aquaculture and aquafeed in Rwanda: current status and perspectives. J Appl Aquacult. 35 (3): 743-764. DOI: https://doi.org/10.1080/10454438.2021.2024315

Njiru JM, Aura CM, Okechi JK. 2019. Cage fish culture in Lake Victoria: a boon or a disaster in waiting? Fish Manage Ecol. 26 (5): 426-434. DOI: https://doi.org/10.1111/FME.12283

Ntakirutimana R, Syanya FJ, Mwangi P. 2023. Exploring the impact of probiotics on the gut ecosystem and morpho-histology in fish: current knowledge of tilapia. Asian J Fish and Aquat Res. 25 (3): 93-112. DOI: https://doi.org/10.9734/AJFAR/2023/V25I3670

O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. 2014. Standards for reporting qualitative research: a synthesis of recommendations. Acad Med. 89 (9): 1245-1251. DOI: https://doi.org/10.1097/ACM.0000000000000388

Opiyo MA, Marijani E, Muendo P, Odede R, Leschen W, Charo-Karisa H. 2018. A review of aquaculture production and health management practices of farmed fish in Kenya. Int J Vet Sci Med. 6 (2): 141-148. DOI: https://doi.org/10.1016/J.IJVSM.2018.07.001

Otieno NE. 2019. Economic impact of predatory piscivorous birds on small-scale aquaculture farms in Kenya. Aquacult Rep. 15: 100220. DOI: https://doi.org/10.1016/J.AQREP.2019.100220

Otieno NE, Wasonga DV, Imboko D. 2021. Pond-adjacent grass height and pond proximity to water influence predation risk of pond fish by amphibians in small fish ponds of Kakamega County, western Kenya. Hydrobiologia. 848 (8): 1795-1809. DOI: https://doi.org/10.1007/S10750-021-04551-8

Pakhira C, Nagesh TS, Abraham TJ, Dash G, Behera S. 2015. Stress responses in rohu, *Labeo rohita* transported at different densities. Aquacult Rep. 2: 39-45. DOI: https://doi.org/10.1016/J.AQREP.2015.06.002

Park S, Lim S-W. 2014. A study about civil liability of live fish transportation contract. J Fish Mar Sci Educ. 26 (5): 959-965. DOI: https://doi.org/10.13000/JFMSE.2014.26.5.959

Peer Mohamed M, Devaraj M. 1997. Transportation of live finfishes and shellfishes. CMFRI Special Publication. 66: 1-43.

Prabu E, Rajagopalsamy CBT, Ahilan B, Jeevagan IJMA, Renuhadevi M. 2019. Tilapia-an excellent candidate species for world aquaculture: a review. Annu Res Rev Biol. 31 (3): 1-14. DOI: https://doi.org/10.9734/ARRB/2019/

V31I330052

Pramod PK, Sajeevan TP, Ramachandran A, Thampy S, Pai SS. 2010. Effects of two anesthetics on water quality during simulated transport of a tropical ornamental fish, the Indian tiger barb *Puntius filamentosus*. N Am J Aquacult. 72 (4): 290-297. DOI: https://doi.org/10.1577/A09-063.1

Prasad S, Bihar S, Suday Prasad I. 2020. Fish transportation and marketing in Dumraon and Buxar, South Bihar, India. J Entomol Zool Stud. 8 (4): 1634-1638.

Saeed R, Zhang L, Cai Z, Ajmal M, Zhang X, Akhter M, Hu J, Fu Z. 2022. Multisensor monitoring and water quality prediction for live ornamental fish transportation based on artificial neural network. Aquacult Res. 53 (7): 2833-2850. DOI: https://doi.org/10.1111/ARE.15799

Sampaio FDF, Freire CA. 2016. An overview of stress physiology of fish transport: changes in water quality as a function of transport duration. Fish Fish. 17 (4): 1055-1072. DOI: https://doi.org/10.1111/FAF.12158

Shabani F, Erikson U, Beli E, Rexhepi A. 2016. Live transport of rainbow trout (*Onchorhynchus mykiss*) and subsequent live storage in market: water quality, stress and welfare considerations. Aquaculture. 453: 110-115. DOI: https://doi.org/10.1016/j.aquaculture.2015.11.040

Singh RK, Vartak VR, Balange AK, Ghughuskar MM. 2004. Water quality management during transportation of fry of Indian major carps, *Catla catla* (Hamilton), *Labeo rohita* (Hamilton) and *Cirrhinus mrigala* (Hamilton). Aquaculture. 235 (1-4): 297-302. DOI: https://doi.org/10.1016/j.aquaculture.2003.12.011

Stieglitz JD, Benetti DD, Serafy JE. 2012. Optimizing transport of live juvenile cobia (*Rachycentron canadum*): effects of salinity and shipping biomass. Aquaculture. (364-365): 293-297. DOI: https://doi.org/10.1016/j.aquaculture.2012.08.038

Syanya FJ, Mathia WM. 2023. Status of fish health and biosecurity management systems in Kenya's aquaculture production units. A case of government authenticated fish hatcheries. Research Square. DOI: https://doi.org/10.21203/rs.3.rs-2430657/v1

Syanya FJ, Litabas JA, Mathia WM, Ntakirutimana R. 2023a. Nutritional fish diseases in aquaculture: a human health hazard or mythical theory: an overview. Eur J Nutr Food Saf. 15 (8): 41-58. DOI: https://doi.org/10.9734/EJNFS/2023/v15i81326

Syanya FJ, Mathia WM, Harikrishnan M. 2023b. Quality and safety concerns of farmed tilapia fish during freezing and frozen storage: review. Asian Food Sci J. 22 (6): 40-58. DOI: https://doi.org/10.9734/AFSJ/2023/V22I6641

Syanya FJ, Winam ZO, Mathia WM. 2024. Vanishing splendor: a comprehensive review of the decline in the original fish fauna of Lake Victoria. Mar Fish Sci. 37 (1): 209-231. DOI: https://doi.org/10.47193/mafis.3712024010107

Treasurer JW. 2010. Remediation of ammonia accumulation during live transport of juvenile cod, *Gadus morhua* L., and the effects of fast period on ammonia levels and water quality. Aquaculture. 308 (3-4): 190-195. DOI: https://doi.org/10.1016/j.aquaculture.2010.08.013

Vanderzwalmen M, McNeill J, Delieuvin D, Senes S, Sanchez-Lacalle D, Mullen C, McLellan I, Carey P, Snellgrove D, Foggo A, et al. 2021. Monitoring water quality changes and ornamental fish behaviour during commercial transport. Aquaculture. DOI: https://doi.org/10.1016/j.aquaculture.2020.735860

Waithanji E, Affognon DH, King'ori S, Diiro G, Nakimbugwe D, Fiaboe KKM. 2020. Insects as feed: gendered knowledge attitudes and practices among poultry and pond fish farmers in Kenya. NJAS - Wagening J Life Sci. 92: 100312. DOI: https://doi.org/10.1016/J.NJAS.2019.100312

Wamukota A. 2010. The structure of marine fish marketing in Kenya: the case of Malindi and Kilifi Districts. West Indian Ocean J Mar Sci. 8 (2): 215-224. DOI: https://doi.org/10.4314/

wiojms.v8i2.56983

Wang W, Zhang Y, Liu Y, Adányi N, Zhang X. 2020. Effects of waterless live transportation on survivability, physiological responses and flesh quality in Chinese farmed sturgeon (*Acipenser schrenckii*). Aquaculture. 518: 734834. DOI: https://doi.org/10.1016/j.aquaculture.2019.734834

Yang Y, Wang T, Phillips CJC, Shao Q, Narayan E, Descovich K. 2021. Knowledge of, and attitudes towards, live fish transport among aquaculture industry stakeholders in China: a qualitative study. Animals. 11 (9): 2678. DOI: https://doi.org/10.3390/ANI11092678

Zahl IH, Samuelsen O, Kiessling A. 2012. Anaesthesia of farmed fish: implications for welfare. Fish Physiol Biochem. 38 (1): 201-218. DOI: https://doi.org/10.1007/S10695-011-9565-1

Zhang Y, Ning Y, Zhang H. 2022. An oxygen forecasting strategy for waterless live fish transportation based on IPSO-GRU Method. In: Li X, editor. Advances in Intelligent Automation and Soft Computing. IASC 2021. Lecture Notes on Data Engineering and Communications Technologies. Vol 80. Cham: Springer. p. 120-128. DOI: https://doi.org/10.1007/978-3-030-81007-8_15

Zhang Y, Wang W, Yan L, Glamuzina B, Zhang X. 2019. Development and evaluation of an intelligent traceability system for waterless live fish transportation. Food Control. 95: 283-297. DOI: https://doi.org/10.1016/j.foodcont.2018.08.018