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RESEARCH PAPER

Fish diseases and health investment needs for the aquaculture sector in Kenya

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Abstract

Aquaculture plays an important role in the provision of food, livelihood and source of income in Kenya. There is a rapid shift from extensive methods to semi-intensive and intensive culture methods with the potential to produce higher output. However, intensification in aquaculture comes with risks of diseases. In recent years, there has been an increase in emerging and re-emerging diseases in aquaculture. Increased occurrence of diseases in aquaculture production systems leads to reduced profits, affecting the social and economic sustainability of aquaculture. To mitigate the negative impact of fish diseases in aquaculture, rapid discovery, characterization, and diagnosis of causative agents and risk factors are crucial for the development of effective control measures. There is need for investment in skilled personnel/researchers, well-equipped and dedicated laboratories, routine surveillance, development of relevant prophylactics, biopesticides and chemo-therapeutants, quarantine facilities. Furthermore, developing the institutional capacity governing aquatic animal health issues and improving the linkages between various stakeholders in the aquatic animal health issues nationally and beyond will be critical in improving fish health and disease control in the aquaculture sector in Kenya.

Introduction

Aquaculture plays a crucial role in meeting the global rising need for high-quality protein derived from animal sources. About 49% of the world's fish production comes from this sector, which has been growing recently (FAO, 2022). Over the past decade, Kenya's aquaculture output has nearly doubled, improving the nutritional status of vulnerable groups, creating job opportunities, increasing income, and fostering economic growth in rural areas (Cheserek et al., 2022). Aquaculture production grew from 12,152 tonnes in 2010 to 22,140 tonnes in 2022, making up 12.7% of the nation's total fish production (KNBS, 2023). However, intensification in aquaculture comes with the risk of disease. Aquaculture has a higher risk of disease than capture fisheries since diseases can spread quickly among aquatic animals raised at high densities in confined environments (Walker and Mohan, 2009). Additionally, new channels for the cross-border spread of aquatic animal diseases have been created due to globalization and the rise in the volume of international trade in aquatic organisms and their associated goods (Rodgers et al., 2011). Furthermore, there's a chance that aquaculture operations in the tropics could eventually have higher cumulative mortalities and quicker disease transmission, and this will probably be made worse by climate change, causing the emergence of more virulent pathogens (Cascarano et al., 2021).

Fish producers in Kenya have suffered enormous losses, ranging from 40% to 100% of the fish in both ponds and cages (Aura et al., 2018; Njiru et al., 2019). This situation deters aspiring farmers from entering the farming industry. Disease outbreaks can have an adverse effect on the economy because they cause significant losses for many fish farmers (Opiyo et al., 2018). This could have an impact on the amount of fish produced, the market supply, and the accessibility of high quality, nutrient-dense fish (Alfred et al., 2020). Fish disease outbreaks raise the cost of production owing to the money lost from fish mortalities, the expense of treatment, and the reduced growth of the fish during recuperation (Alfred et al., 2020). However, aquaculture and international trade will continue to grow despite the potential risks of diseases.

Therefore, as fish farming expands globally, it is necessary to create comprehensive health management practices that include identifying the cause of diseases, enhancing disease monitoring, developing novel approaches for diagnosing diseases, creating efficient and innovative vaccines and antiviral medications, and utilizing current technologies to manage fish diseases (Akoll & Mwanja, 2012; Syanya & Mathia, 2023). For the implementation of the measures outlined above, this paper provides insights on the disease status of aquaculture fish and fish health investment needs for the aquaculture sector in Kenya.

Materials and Methods

In order to produce a thorough review of the aquaculture fish diseases and fish health investment needs in Kenya, a narrative review approach was used. The review focused on the status of fish diseases in the Kenyan aquaculture sector, their socio-economic impact in the aquaculture sector, management challenges and solutions to fish diseases, and investment needs to improve fish health in the aquaculture sector in Kenya. To this end, a wide range of phrases (closely related to fish diseases) were searched in the scholarly platforms of Science Direct, Research Gate, Google Scholar, and Web of Science. A literature review was done from 40 research publications that satisfied the requirements of this study. The review process is summarized in Figure 1.

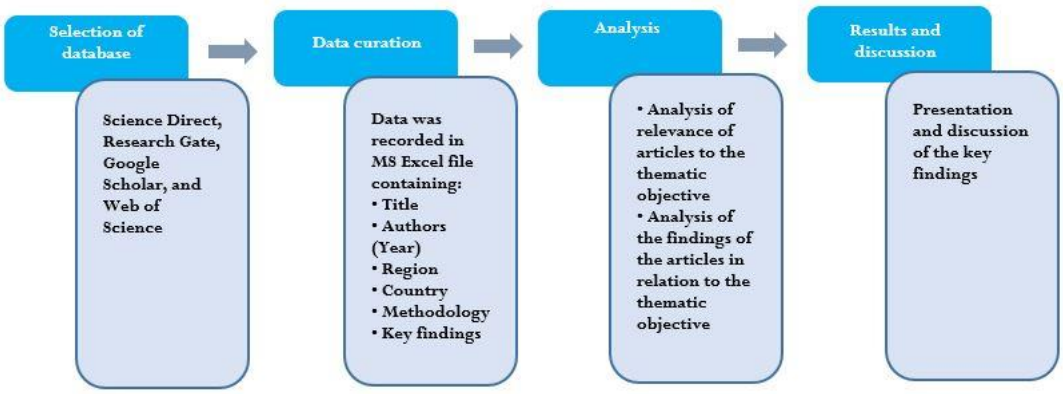

Figure 1. Flowchart of the review process of the fish diseases and fish health investment needs for aquaculture sector in Kenya

Results

Fish disease status in the Kenyan aquaculture sector

Very limited information exists on disease occurrence in the Kenyan aquaculture sector. Most studies on fish health have focused on parasites in the two most cultured species, *Oreochromis niloticus* and *Clarias gariepinus* (Akoll & Mwanja, 2012; Ochieng et al., 2012; Opiyo et al., 2018), focusing on the parasite descriptions, biology and pathology. The dearth of information regarding fish diseases may be attributed to several factors, including inadequate diagnostic facilities, a shortage of personnel with experience in fish health, high diagnostic costs, a lack of veterinary laboratories equipped to identify pathogens, a lack of disease outbreak reports as a result of farmers' poor documentation, and the socioeconomic status of the farmers (Akoll & Mwanja, 2012). On the other hand, some farmers have reported fish deaths on their farms, with fish mortalities ranging from 40 to 100% in ponds and cages (Aura et al., 2018; Njiru et al., 2019). Although this is typically linked to issues with water quality, since no diagnosis is made at the farm level to rule out infections, it is possible that the mortalities are health-related. The majority of small- and medium-scale farmers don't bother determining the reason for fatalities, and when they do, they seek advice from universities, or fisheries officers, who are likewise poorly informed about fish health (Akoll & Mwanja, 2012). According to a 2014 study, the majority of the fish stocks in certain hatcheries were lost due to bacterial and fungal infections (Njagi, 2016). The small-scale hatcheries were found to experience more mortality due to insufficient biosecurity measures and subpar infection control procedures. The majority of diseases in fish farms that are documented are fungal, primarily saprolegniasis (Figure 2), and bacterial, mostly haemorrhagic and pop eye diseases (Akoll & Mwanja, 2012; Walakira et al., 2014).

Streptococcus iniae has been found in some hatcheries (Figure 3) causing infection in the fish, particularly the freshly stocked fish larvae, which often display a C-shaped curvature (Florio et al., 2009; Walakira et al., 2014). Grow-out *O. niloticus* have also been affected by fish lice (*Argulus* spp.), while *C. gariepinus* have been affected by freshwater white spot disease (*Ichthyophthirius multifiliis* (Figure 4) (Njagi, 2016). Disease occurrences in farms have been attributed to poor management practices such as the use of on-farm formulated feed with high bacterial load, and the use of untreated water directly from the source (Njagi, 2016, Walakira et al., 2014). In most cases, water is used straight from a river or stream, introducing high bacterial loads that impact younger fish more than adults, indicating substandard hatchery operations used in Kenyan aquaculture sector (Njagi, 2016). The common bacterial infections affecting pond fish cultured in Kenya are caused by *Aeromonas hydrophila*, *Pseudomonas fluorescens* and *P. aeruginosa*, *Edwardsiella tarda*, *Flavobacterium columnare*, *Mycobacterium fortuitum* and *S. iniae* (Akoll & Mwanja, 2012). Signs of bacterial and fungal infections have been observed in cages including fin rot, cloudy eyes, and skin sores (Aura et al., 2018), as shown in Figure 5.

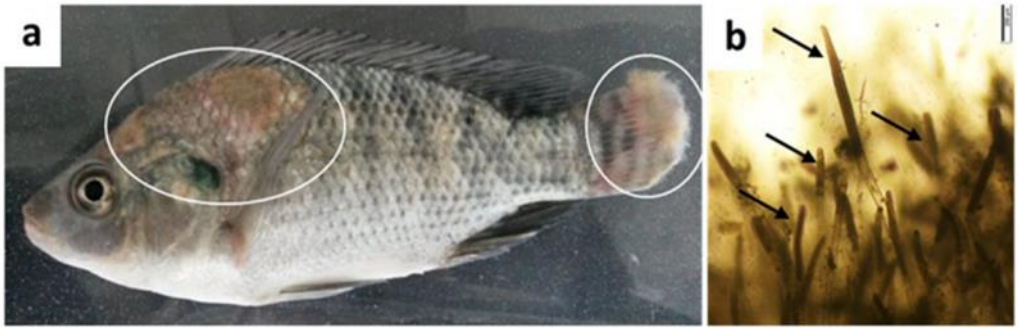

Figure 2: (a) Nile tilapia showing clinical signs of Saprolegniasis, white to grey patches on the external body surfaces and tail. (b) Microscopic examination of wet mount preparation of *Saprolegnia* showing characteristic aseptate hyphae and zoosporangia (arrows) (Elgendy et al., 2023).

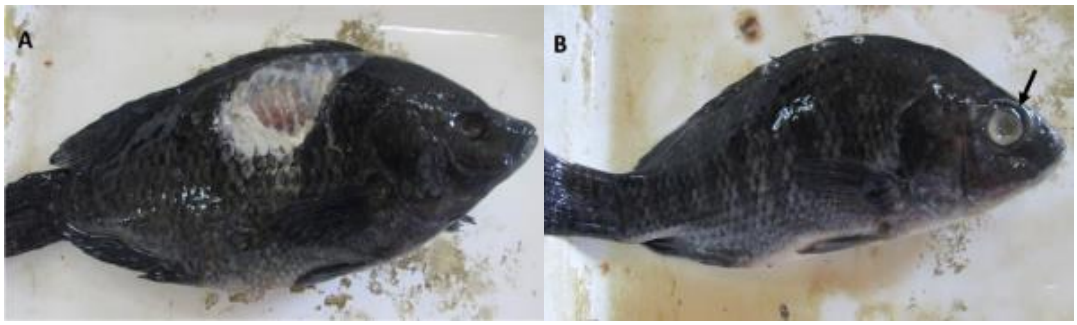

Figure 3: Photograph showing a skin ulcer (A) and corneal opacity (B) from a field outbreak of streptococcosis in tilapia (*Oreochromis niloticus*). Arrow points to a sunken eye, another common finding (Bwalya et al., 2020).

Figure 4: White spots on the skin of a catfish caused by *Ichthyophthirius multifiliis* (Durborow et al., 2015).

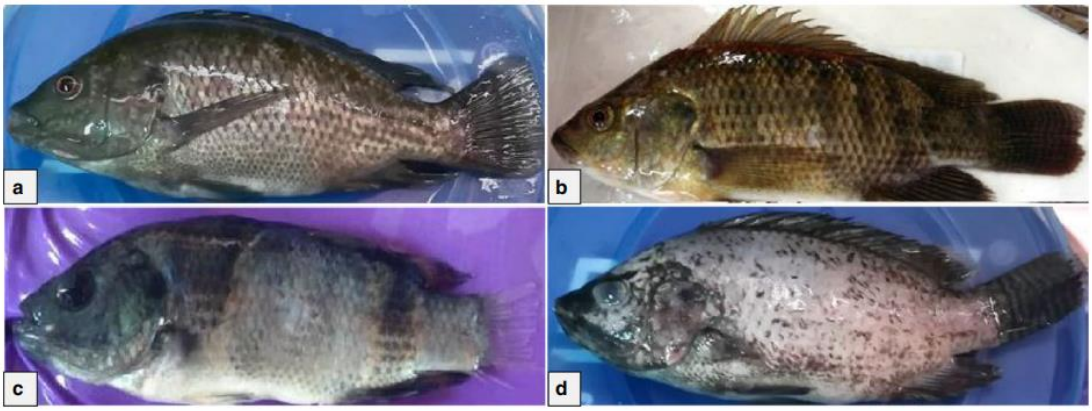

Figure 5: Nile tilapia showing gross signs of (a) cutaneous haemorrhages; (b) irregular scale loss and dark discoloration; (c) severe scale loss and fin rot and; (d) peeled skin (Rao et al., 2021).

Socio-economic impact of fish diseases in Kenya's aquaculture sector

The aquaculture sector, like other farming systems, is faced with the challenge of disease caused by viruses, bacteria, fungi, parasites and other undiagnosed and emerging pathogens (Alfred et al., 2020). Fish disease is one of the bottlenecks impacting the commercialization of the aquaculture industry in Kenya, thus impeding both economic and social development (Munguti et al., 2021a). Although little information is available in the scientific literature, Bondad-Reantaso et al. (2005) noted that fish diseases in aquaculture can have significant and varied socio-economic impacts which include and are not limited to:

a) Loss of income and livelihoods- fish diseases can cause significant financial losses to aquaculture farmers, especially smallholder ones who mostly rely on aquaculture for their livelihoods. Fish mortality due to disease infection reduces the farmer's stock and, consequently, their income.

b) Food insecurity and malnutrition- aquaculture plays a critical role in the provision of protein-rich diet among most communities in Kenya. Therefore, fish disease outbreak reduces the availability of fish for consumption, leading to food shortages and potential malnutrition, particularly among vulnerable populations like children.

c) Loss of employment- the aquaculture industry creates employment opportunities along the value chain, including farm workers, processors, distributors, and retailers. The outbreak of fish diseases can disrupt these employment opportunities, leading to job losses and decreased economic activity in affected communities.

d) Decreased investment and market confidence- frequent outbreaks of fish diseases can discourage investors and development partners from funding aquaculture projects due to the perceived risks involved. The decreased investment can stifle the growth of the aquaculture sector and hinder its potential to contribute to the country's economic development.

Fish disease management challenges and possible solutions in Kenya's aquaculture sector

Challenges

Health services in aquatic animals are comparatively underdeveloped as compared to health services in terrestrial animals (Peeler & Taylor, 2011; Scarfe & Palic, 2020). There is a dearth of information about disease outbreaks in fish farms in Kenya. The knowledge gap is caused by a number of factors, including inadequate diagnostic facilities, a shortage of personnel with experience in fish health, high diagnostic costs, a dearth of veterinary laboratories equipped to identify pathogens, a lack of outbreak reports as a result of farmers' poor record-keeping, and the socioeconomic status of the farmers (Akoll & Mwanja, 2012; Opiyo et al., 2018). According to Akoll and Mwanja (2012), inadequate fish health services in Kenya are caused by the misconception that fish do not become sick. However, this belief is beginning to change in

Kenya and other developing countries where fish disease outbreaks have had catastrophic effects on the economy (Syanya & Mathia, 2023; Zornu et al., 2023).

Possible solutions

Some of the ways fish farmers can overcome disease management challenges in Kenya, as discussed in this section, include proper nutrition and stocking density, implementing best management practices, selective breeding, surveillance and monitoring, vaccines administration and implementing biosecurity measures.

Proper nutrition

Despite significant progress in understanding fish's nutrient requirements, issues related to dietary imbalances continue to affect farmed fish (Syanya et al., 2023). Providing fish with an appropriate diet is crucial for their general health and well-being, in addition to promoting growth and preventing nutritional deficiencies (Bandara, 2018; Munguti et al., 2023).

Fish farmers should thus make sure that their fish feed is properly stored in a dry, cool environment. This is significant because moldy feedstock can harbor *Aspergillus flavus*, which can produce aflatoxins that are detrimental to fish and, to a lesser extent, humans (Syanya et al., 2023). In order to prevent the spread of infections to healthy fish, fish farmers should also refrain from feeding fish with fish waste and viscera. Such feed may weaken the fish's immune system and prevent them from receiving a nutritionally balanced diet, leaving them more susceptible to pathogenic diseases (Syanya et al., 2023). Additionally, hygienic dry pellet diets with the right amount of vitamins and minerals added should be utilized to improve fish immunity and growth (Bandara, 2018).

Proper stocking density

The health of fish relies on maintaining the proper stocking density. Fish farmers must ensure that the number of fish in the culture system is appropriate and does not lead to stress or overcrowding (Syanya et al., 2023). Overstocking can cause cannibalism because of competition for food, in addition to causing skin injuries. The skin serves as the main defence against viruses; any damage to the skin can facilitate the entry of pathogens (Wanja et al., 2020). Furthermore, overstocking in intensive systems causes fish faeces to accumulate, which increases ammonia levels in the water and results in poor water quality (Jobling et al., 2011).

Implementing best management practices

Farmers can prevent disease outbreaks by implementing best management practices. This entails keeping the pond environment clean by managing silting, plants, and the right balance of phytoplankton and zooplankton, as well as guaranteeing good water quality in the culture system (sufficient water and dissolved oxygen, and free from pollutants) (Wanja et al., 2020; Belfiore et al., 2021). Other practices include preventing stress in fish by managing stocking density, separating different-sized fish to prevent fighting, offering sufficient food supply, and treating the fish with care (Weitzman et al., 2021; Syanya et al., 2023). Additionally, farmers should keep disease-causing organisms out of canals and ponds by eliminating wild fish and using screens to block their access, regulating predators (birds and mammals), and routinely sanitizing ponds to eliminate disease organisms and their intermediate hosts (Wanja et al., 2020; Kumar et al., 2021). Other practices include avoiding mixing water among ponds, and, in the event of a disease epidemic, removing sick fish and burying diseased fish with quicklime away from the culture facilities (Kyule et al., 2022).

Selective breeding

There is a great deal of opportunity to select for enhanced resistance to important diseases because disease resistance is nearly always heritable (Houston, 2017). Since disease resistance is nearly always heritable, selective breeding can be utilized as a potentially effective way to control diseases (Megahed, 2019). Heritable qualities that can be enhanced by selective breeding for long-term genetic gain and trait enhancement include body weight, survival, and disease resistance (Abwao et al., 2023).

Surveillance and monitoring

Timely detection of disease outbreaks will help to stop infections from spreading and lower fish mortalities. While aquaculture production has

intensified in Kenya, there hasn't been a corresponding increase in the adoption and implementation of advanced management strategies for disease control, prevention, and monitoring. This has left aquaculture vulnerable to numerous disease outbreaks, including bacterial, viral, fungal, and parasitic incidents (Kyule et al., 2022).

Vaccine administration

Improving vaccination is one of the most critical and perhaps the most effective methods for preventing and controlling infectious diseases in fish aquaculture (Assefa et al., 2018). Currently, there is no information available regarding Kenya's regulations regarding the use of probiotics, antibiotics, and vaccines in aquaculture (Opiyo et al. 2018). A study by Syanya & Mathia (2023) reported that there have not been any cases of the use of vaccines in Kenya's aquaculture production units.

Implementing biosecurity measures

In a controlled aquatic environment, a higher percentage of fish infections (90%) are linked to inappropriate husbandry techniques and insufficient implementation of biosecurity measures (Wanja et al., 2020). Biosecurity is a set of management techniques that minimize the likelihood of pathogenic microbes infiltrating areas (Huber et al., 2022). Sanitation and disinfection are two important biosecurity practices that should be paired with pathogen-free seed selection and targeted treatments to either completely eradicate or significantly reduce infections to non-infectious levels **(**Dewulf & van Immerseel, 2019)**.**

Although not well established, implemented biosecurity measures in Kenya's aquaculture systems include limiting visitors' movement in the hatchery, cleaning of culture units, stocking of disease-free broodstock, use of protective clothing, disinfection of equipment, use of foot baths, use of good water quality on the farm, and water temperature maintenance (Syanya & Mathia, 2023).

Investment needs for fish health management and disease control in Kenya's aquaculture sector

Some of the suggested investments to improve fish health and disease control in the aquaculture sector in Kenya include and not limited to:

Investment in skilled personnel/researchers

Fish health issues have received little attention or documentation in Kenya up until recently, with the majority of studies concentrating on parasitic diseases. Though small advances have been made in that direction, a review by Akoll & Mwanja (2012) indicated that there was very little research on bacterial, fungal, and viral infections in the region. The paucity of outbreak reports due to inadequate record keeping, the high expense of detecting and identifying such infections, and the lack of diagnostic infrastructure were all cited as contributing factors. This finding holds to this day (Syanya & Mathia, 2023). As a result, funding for the education and training of fish health specialists is required to deal with issues related to disease diagnosis, treatment, and the appropriate use of medications in the sector.

Investment in research on development of relevant prophylactics and chemo-therapeutants

Chemotherapeutants are frequently used in pond culture in Kenya to treat a wide range of illnesses (Opiyo et al., 2020). Even while biotherapy has undergone a number of experiments in the lab, it is not yet feasible to apply such treatments widely (in the culture systems) (Huo et al., 2024). As a result, greater funding is needed to develop preventatives for widespread use in the field. Furthermore, a closer examination of some of the medications used, such as formalin (a carcinogen used to treat a range of ectoparasite illnesses), highlights the pressing need to create safer alternatives for both farmers and consumers (Munguti et al., 2021a).

Investment in well-equipped laboratories

There is need of having well-designed and equipped laboratories in Kenya, especially in light of the growing investments in aquaculture. For instance, the World Organization for Animal Health has not yet accredited Kenya's specialized fish diagnostic facilities (Opiyo et al., 2018).

Investment in the institutional capacity governing aquatic animal health issues

Legislative and policy instruments must be repositioned to take aquaculture development into account, which considers concerns about the health of aquatic animals (Akoll & Mwanja, 2012). Regulation of drug application in aquaculture is necessary to avoid issues of environmental residue and the ensuing drug resistance (Defoirdt et al., 2011).

Investment in routine surveillance

The creation and execution of regular surveillance and monitoring programs for aquatic animal diseases are essential. This is due to the fact that surveillance makes it feasible to identify diseases long before they cause significant losses (Matolla, 2019). Enhancing biosecurity governance, expertise in fish disease pathology, diagnostics, surveillance, emergency preparedness, and networking assistance for aquatic animal health management are all necessary.

Investment in quarantine facilities

The globe is believed to have become a global village recently, with a great deal of trade occurring worldwide. Opiyo et al. (2018) pointed out that in Kenya, there are no quarantine facilities and only rudimentary biosecurity measures are in place for the monitoring of new imports. Therefore, there is a chance that exotic diseases will be introduced into Kenya's systems as a result of the transfer of fish fry and brooders from other nations, which could lead to the spread of infections and diseases through the movement of live fish. The lack of infrastructure for quarantine and the infrequent risk analysis procedures applied to the trade in live aquatic animals raise the possibility of disease infections spreading quickly both within and across nations if these practices are maintained (Bondad-Reantaso, 2005; Akoll & Mwanja, 2012). Therefore, investment in the quarantine facilities will be critical to curb the above risks.

Investment towards improving the linkages between various stakeholders in the aquatic animal health issues nationally and beyond

Most research findings are not available to the fish farmers due to the weak linkages between research and industry (Munguti et al., 2021b). Building capacities and establishing organizations or cooperatives that can help address aquatic animal health issues can be achieved through investing in the strengthening of relationships between various sectors working in the animal health aspects. Additionally, funding local officers' training and capacity building can greatly aid in raising understanding of how to address aquatic health-related issues.

Conclusions

Fish health issues have received little attention or documentation in Kenya’s aquaculture sector. It is important to adopt a multi-disciplinary approach that utilizes a combination of techniques to fully understand the biology of emerging and re-emerging diseases in aquaculture. To improve aquaculture production, and the ability of aquatic species to adapt to changing health issues, a comprehensive approach that includes all components of the epidemiologic triads is required for aquatic health management. Additional research and efforts in this field should continue to explore the intricate interactions between the host, pathogen, and environment, aiming to develop tailored strategies and solutions to address the unique needs and challenges of different aquatic species and habitats. Fisheries extension personnel, researchers and veterinarians need to have adequate background information on aquatic animal disease and health management to understand the problems and needs of the fast-growing aquaculture industry in Kenya. There is a need to enhance awareness of the importance of health management in the aquaculture industry through education and information dissemination.

Conflict of interest

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

Ethical approval

There were no human or animal subjects used in this study. Therefore, no ethical approval was needed.

Informed consent

Not available.

Data availability statement

There was no data used in the present study.

Funding organizations

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Author contributions

Jonathan Munguti: Conceptualization; Writing - original draft, **Jimmy Mboya**, **James Kirimi, Domitila Kyule, Jacob Iteba**: Writing - original draft, Writing - review & editing. **Esther Magondu,:** Writing - review & editing, **Kevin Obiero**: Writing - original draft; Writing - review & editing, **Elick Otachi**, **Florence Thiakunu, Kevin Ouko, Mary Opiyo**: Validation; Writing - review & editing

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