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RESEARCH

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# Status of fish health management and biosecurity measures in fish farms, cages and hatcheries in Western Kenya

Domitila Kyule-Muendo[1], Elick Otachi[2*], Fonda Awour[1], Erick Ogello[3], Kevin Obiero[4], Jacob Abwao[1], Cecilia Muthoni[5] and Jonathan Munguti[1]

## Abstract

**Background:** Aquaculture is one of the critical sectors contributing to food and nutrition security, income and employment opportunities to millions of people, and is currently the fastest growing food-producing sector globally. With the global increase in aquaculture production, focus on biosecurity and fish health management is becoming increasingly important to address the risks and impacts of aquatic diseases. Within the framework of adaptive research, this study aimed at assessing the levels of awareness and preparedness of fish farmers in Western Kenya to meet fish health management and biosecurity requirements as important parameters determining the success of their farming activities.

**Methods:** A total of 504 fish farmers were interviewed using a pre-tested questionnaire generated by a computer-aided personal interview (CAPI). The data collected was summarized using descriptive statistics using SPSS version 25. The homogeneity of frequency data of all the parameters between the three counties was tested using a non-parametric Pearson Chi-Square test at $\alpha = 0.05$.

**Results:** The key findings were that 76.1% of the fish farmers reported mortalities in their farms, with 2.3% reporting mortalities above 50% of the stocked fish, but with a majority (85.5%) reporting loss of up to 10%. In extrapolation, the total loss from the farms correlates with stagnation in aquaculture production in Kenya.

**Conclusions:** This study concludes that there is a paucity of knowledge on fish health management systems and biosecurity measures which presents a serious threat to aquaculture production in the studied counties and poses a great risk to trans-boundary live fish trade between Kenya and her neighbouring countries. Although fish farming is a promising area, it has had so many challenges among them high mortality rates. In China and other Asian countries, which are the world leaders in aquaculture production, they are making headway in fish health management and biosecurity. This study recommends the development of a coordinated awareness campaigns on fish health management and biosecurity measures to fish farmers in Kenya.

**Keywords:** Fish, Health, Management, Biosecurity, Aquaculture, Kenya

## Introduction

The increasing human population expected to add another 2 billion people by 2050 demands a parallel increase in food security. The importance of fish as a source of protein is exemplified by the 2030 Agenda of UN member states that sets aims for the contribution

*Correspondence: elick.otachi@egerton.ac.ke; elickotachi@gmail.com
[2] Department of Biological Sciences, Egerton University, P.O. Box 536, Egerton, Kenya
Full list of author information is available at the end of the article

to fisheries and aquaculture towards food security and nutrition in the use of natural resources (FAO-SOFIA 2016). Aquaculture has been identified as one of the critical sectors contributing to food and nutrition security, income and employment opportunities to millions of people and is now the fastest growing food-producing sector globally (FAO 2020). In Kenya, aquaculture is mainly divided into mariculture, which is still at an infancy stage, and a more progressive freshwater aquaculture (Opiyo et al. 2018). The Government of Kenya has recognized this critical sector and has continued to invest towards intensification of aquaculture through different initiatives. For instance the economic stimulus programme (ESP) which resulted to a significant expansion from 4218 metric tonnes (MT) in 2006 to a peak of 24,096 in 2014 (Munguti et al. 2017; Obiero et al. 2019). As a result, freshwater aquaculture has been prioritized in some counties such as Kakamega, Siaya and Busia, with many fish farmers venturing into cage fish farming in the Winam Gulf of Lake Victoria (Munguti et al. 2014; Aura et al. 2018; Njiru et al. 2018). Intensive fish farming inevitably leads to increased prevalence of fish diseases and environmental contamination. Diseases are a direct hindrance to sustainability of aquaculture and can lead to reduced growth in the industry (for example, Norwegian Salmon industry 1980's and today) or near total collapse (Chilean Salmonid Industry in 2007). In general, diseases have caused serious economic losses to finfish aquaculture around the world (Mustafa et al. 2001; Johnson et al. 2004; Sahoo et al. 2013; Monir et al. 2015). For example, in Brazil, fish losses due to mortalities have been estimated as leading to a total loss of US $84million annually (Tavares-Dias and Martins 2017).

The development of aquaculture in Africa has not been paralleled by measures that support its growth, namely disease surveillance, control and prevention, quality feed provision and water quality analysis and management practices.

Therefore, aquaculture has been associated with some challenges such as fish diseases and parasites (Shitote et al. 2013; Munguti et al. 2014; Ojwala et al. 2018; Opiyo et al. 2018). As a result, there should be adequate biosecurity measures to reduce economic losses through fish mortalities and unnecessary treatment costs (Bhujel 2014). Fish health management is a term used in aquaculture to describe management practices, which are designed to prevent fish diseases. A sustained and consistent practice of biosecurity is becoming an increasingly critical requirement for successful aquaculture (Noble and Summerfelt 1996; Browdy and Bratvold 1998; Timmons et al. 2002; Lee and O'Bryen 2003; Delabbio et al. 2005; Eissa et al. 2016). According to World Organization for Animal Health (OIE 2019), the term biosecurity can be defined as a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of pathogenic agents to, and from and within an aquatic animal population. Therefore, unless governments are informed about the implications of fish diseases for the development of the fisheries and aquaculture sectors, and they act upon this information increasing support for fish health management, massive fish mortalities and economic losses may ensue (Akoll and Mwanja 2012). According to the recently held Aquatic Biosecurity Governance Workshop in Durban, South Africa in the year 2014, African states were urged to be proactive rather than reactive to a healthy aquaculture production that protects producers and the emerging sector from the risks and threats of aquatic pathogens and diseases (FAO 2018). Globally, the risks of pathogen introductions into aquaculture systems are on the rise (Kent 2000). This is due to different hosts being reared in new geographic areas, or by indigenous species being reared in a different environmental condition, i.e. the marine netpen. Examples of the former include *Kudoa thyrsites* (Myxozoa) and *Hemobaphes disphaerocephalus* (Copepoda) infections in Atlantic salmon (*Salmo salar*) reared in the Pacific Northwest, *Ceratothoa gaudichaudii* (Isopoda) infections in Atlantic salmon reared in Chile, *Neoparamoeba* (=*Paramoeba*) sp. (Sacromastigophora) from salmonids reared in Tasmania, and *Stephanostomum tenue* (Digenea) infections in rainbow trout (*Oncorhynchus mykiss*) reared in Atlantic Canada (Kent 2000). In addition, some previous studies have strongly recommended the need for baseline studies on fish emphasizing the health of farmed fish and health management practices to provide basic information for planning necessary interventions for fish health management in Kenya (Opiyo et al. 2018). Therefore, the aim of this study was to assess the fish health management and biosecurity practices in the Counties of Kakamega, Siaya and Busia, Kenya, where aquaculture has been prioritized for food security in the respective County Integrated Development Plans.

## Materials and methods

### Description of the study area

This study covered selected fish farms, cage farms and hatcheries in three counties in Western Kenya namely Kakamega, Siaya and Busia as shown in Fig. 1. A brief description of the characteristics of the three Counties is given below:

#### *Kakamega County*

Kakamega County is located in the Western part of Kenya and borders Vihiga County to the South, Siaya

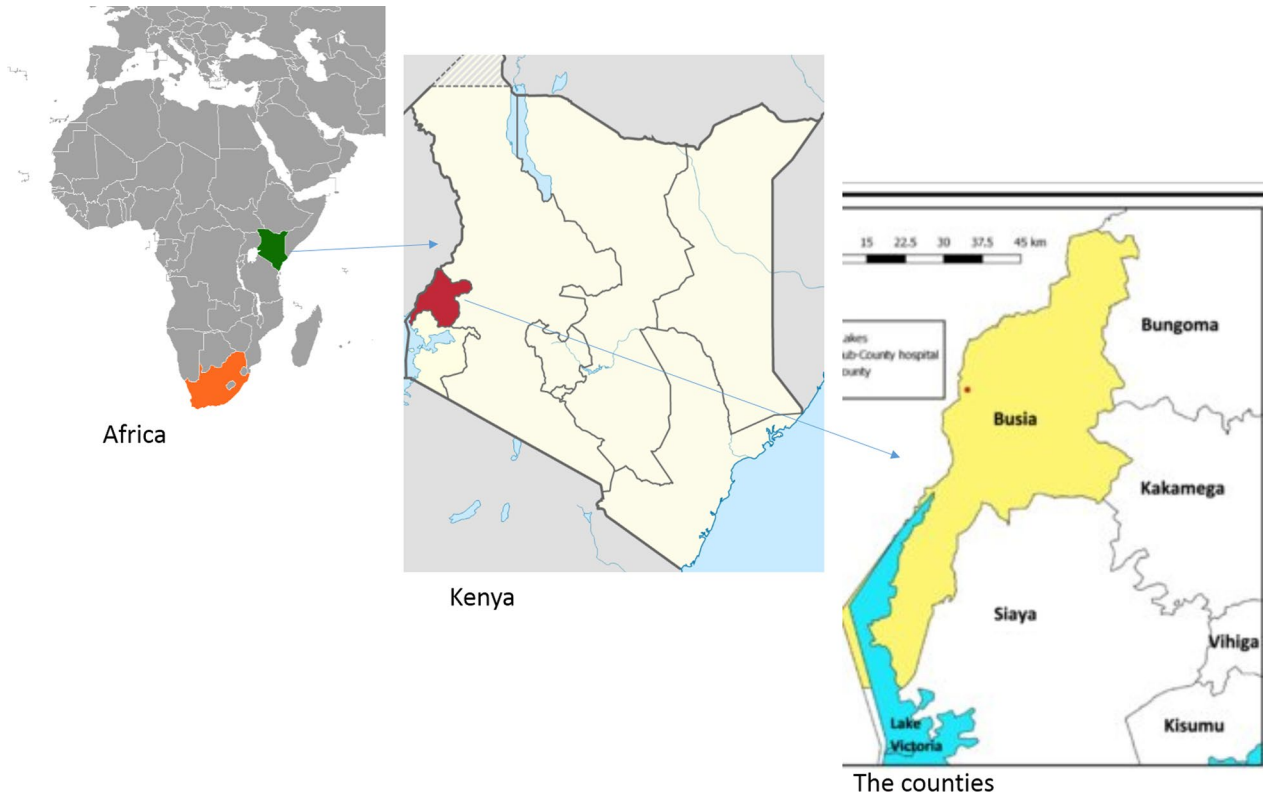


**Fig. 1** Showing **a** the map of the study area within Kenya, and **b** showing the sampled farms

County to the West, Bungoma and Trans Nzoia Counties to the North and Nandi and Uasin-Gishu Counties to the East. The County covers an area of 3051.3 km$^2$ and is the second populous county after Nairobi with the largest rural population. The altitude of the county ranges from 1240 to 2000 m above sea level. The southern part of the county is hilly and is made up of rugged granites rising in places to 1950 m above sea level. There are also several hills in the county such as Misango, Imanga, Eregi, Butieri, Sikhokhochole, Mawe Tatu, Lirhanda, Kiming'ini among others. There are ten main rivers in the county namely; Nzoia, Yala, Lusumu, Isiukhu, Sasala, Viratsi, Kipkaren, Kamehero, Lukusitsi and Sivilie. The annual rainfall in the county ranges from 1280.1 mm to 2214.1 mm per year. The rainfall pattern is evenly distributed all year round with March and October receiving heavy rains while December and February receives light rains. The temperatures range from 18 °C to 29 °C. According to the 2019 Population and Housing Census, the County population was 1,867,579. The county has a population growth rate of 2.5% with a population projection of 2,132,318 by the end of the year 2019 (County Government of Kakamega 2018).

***Siaya County***

Siaya County is one of the six counties in Nyanza region. It has a land surface area of approximately 2530 km$^2$ and water surface area of approximately 1005 km$^2$. It borders Busia County to the North West, Vihiga and Kakamega counties to the North East, Kisumu County to the South East and Homa Bay County across the Winam Gulf to the South. The water surface area forms part of Lake Victoria. It approximately lies between latitude 0° 26′ S to 0° 18′ N and longitude 33° 58′ and 34° 33′ East. There are three major geomorphological areas in the county namely: Dissected Uplands, Moderate Lowlands and Yala Swamp. These areas have different relief, soils and land use patterns. The altitude of the County rises from 1140 m on the shores of Lake Victoria to 1400 m above sea level on the North. The County experiences a bi-modal rainfall, with long rains falling between March and June and short rains between September and December. The relief and the altitude influence its distribution and amount. Siaya County is drier in the southern part towards Bondo and Rarieda sub-counties and is wetter towards the higher altitudes in the northern part particularly Gem, Ugunja and Ugenya sub-counties. On the highlands, the rainfall ranges between 800 mm and 2000 mm while lower areas receive rainfall ranging between 800 and 1600 mm.

Temperatures vary with altitude rising from 21 °C in the North East to about 22.5 °C along the shores of Lake Victoria while in the South, it ranges from mean minimum temperature of 16.3 °C and mean maximum temperature of 29.1 °C. Humidity is relatively high with mean evaporation being between 1800 mm to 2200 mm per annum within the County. The relative humidity ranges between 73% in the morning and 52% in the afternoon (County Government of Siaya 2018). According to the 2019 Population and Housing Census, the County population was 993,183.

### *Busia County*

Busia County is situated in western Kenya and serves as the gateway for Kenya to the neighboring Uganda, with two border crossing points at Busia and Malaba towns. Agriculture, fishing and trade are the main economic activities in Busia County. Being the entry points between Kenya and Uganda, Busia and Malaba towns are thriving trade towns where livestock, agricultural products and manufactured goods are traded. Busia's climate is conducive for agriculture. Some of the crops that are grown within the county in small scale include maize, beans, sweet potatoes, millet, cassava, cotton, tobacco and sugar cane. Fishing is also a major economic activity in Busia, due to the nearby Lake Victoria that supports a huge population of fish including Nile Perch and Tilapia. Most parts of Busia County fall within the Lake Victoria Basin. The altitude varies from about 1130 m above sea level at the shores of Lake Victoria to a maximum of about 1500 m above sea level in the Samia and North Teso Hills. Busia County receives annual rainfall of between 760 and 2000 mm. 50% of the rainfall falls in the long rain season which is at its peak between late March and late May, while 25% falls during the short rains between August and October. The dry season with scattered rains falls from December to February. The temperatures for the whole county are more or less homogeneous. The annual mean maximum temperatures range between 26 °C and 30 °C while the mean minimum temperature range between 14 °C and 22 °C (County Government of Busia 2018). According to the 2019 Population and Housing Census, the County population was 893,681.

### *Description of the fish ponds and cages*

The fish ponds are mainly earthen ponds of size 300m$^2$ (Fig. 2). The cages are floating cages of sizes of 4 m*5 m*4 m (Fig. 3). The hatcheries are of different sizes with the most modern being Wakhungu hatchery in Busia County (an example showing Labed Cash hatchery, Kakamega County (Fig. 4)).

**Fig. 2** Showing some earthen fish ponds in Western Kenya

**Fig. 3** Showing some fish cages in part of Lake Victoria in Western Kenya

**Fig. 4** Showing one of the hatcheries in Western Kenya

### Sampling technique

A modified systematic random sampling technique was used for sample selection. The rationale for choosing this technique is its simplicity and it also gives assurance that the population is evenly sampled. Field plan was prepared and finalized after consultation with the stakeholders. There were nine, Focus Group Discussions (FGDs), with three in each county and five (5) Key Informant Interviews with the major stakeholders. Mixed-sex groups were used for the FGDs since the survey was not considered to include 'gender sensitive' topics. The FGDs were chosen in such a way to ensure they included a minimum of 30% female respondents.

### Sample size determination

The sample of this research was calculated by using the formula of Yamane (1973) with 95% confidence level.

The calculation formula was as follows:

$$n = \frac{N}{1 + N(e)^2}$$

where n = sample size required; N = number of people in the population; e = allowable error (%).

For the three counties, the total population of 3,754,443, and the target sample size was approximately 400. Considering that not all the populace are fish farmers, this study included all active farmers, with active fish farms, cages and hatcheries. A total of 504 farmers from three counties spread over 11 sub counties were interviewed based on their consent to participate and availability at the time of the study (Table 1).

### Data collection

A semi-structured questionnaire was used for data collection using computer aided personal interview (CAPI) and data stored in Open Data Kit (ODK). The questionnaire was used to collect information on fish health management, biosecurity measures, common fish diseases and parasites, fish mortality and mitigation measures. Prior to the main survey, the questionnaire was pretested through ten in-depth interviews with the smallholder fish farmers in the project areas with the aim of testing and validation of the various aspects of the survey including data collection instruments, methodology and field logistics.

### Data analysis

The data collected was summarized using descriptive statistics using SPSS version 25. The number of valid cases for data analysis was 495. The homogeneity of frequency data of all the parameters among the three counties was tested using a non-parametric Pearson Chi-Square test at $\alpha = 0.05$. To test for association between mortalities and fish health management practices including biosecurity, the reported practices were categorized into distinct groups and responses tallied and a Fisher's exact test was performed using R programming by collapsing the practices into two: those who practices some form of fish health management and those who do not.

**Table 1** Showing the number of fish farmers who were interviewed during the study and their distribution within the Counties

| County | Sub county | Number of farmers |
|---|---|---|
| Siaya | Bondo | 41 |
| | Rarieda | 9 |
| | Ugunja | 26 |
| Kakamega | Lurambi | 69 |
| | Malava | 48 |
| | Navakholo | 91 |
| Busia | Bunyala | 82 |
| | Butula | 98 |
| | Malava | 1 |
| | Samia | 2 |
| | Teso South | 37 |
| Total | | 504 |

## Results

### Fish health management systems

From this study, 76.1%, (n = 243) of the fish farmers reported mortalities in their farms (Fig. 5a), with 2.3% reporting mortalities above 50% of the stocked fish (Fig. 5b), but with a majority 85.5% reporting loss of up to 10% (Fig. 5b). There was no homogeneity between the three counties in terms fish mortality levels (Pearson Chi-Square test = 94.536, $p < 0.005$). Although these numbers seem to be low, if one extrapolates the total loss from the farms, then one can know why aquaculture production is stagnating. For the average farmer with a fish pond of 300 $m^2$, 10% loss in all the farms amounts to approximately 25MT for Western fish ponds annually, and if it is the cages, the loss is even higher. Interestingly, 66.7%, (n = 243) of the fish farmers have never seen a sick fish (Fig. 5c). However, some of the fish farmers (32.5%) seemed well aware that water quality management was critical to avoid stressing the fish, hence controlling fish diseases (Fig. 5d).

### Biosecurity measures

Some management practices reported included choosing springs/streams as the source of water to the farms (49%), use of inlet screens (2%) to keep off unwanted organisms, use of liming (5%) to ensure the farms are well

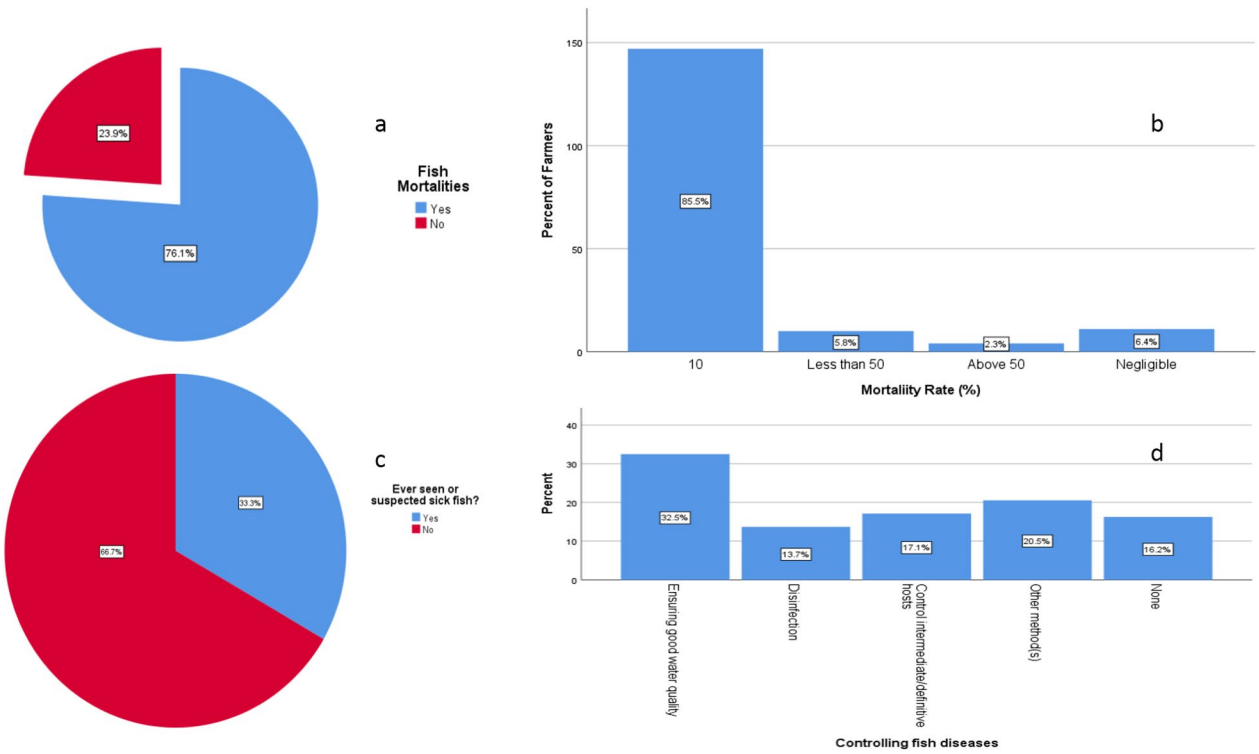


**Fig. 5** Showing **a** proportion of fish farmers who experienced losses in their farms in western Kenya, **b** mortality rates, **c** proportion of fish farmers who have seen sick fish and **d** the methods used in controlling fish diseases

buffered hence moderate the pH fluctuations and regular water exchanges in fish ponds were reported. There was no homogeneity between the three counties in terms of biosecurity measures (Pearson Chi Square test = 106.170, $p < 0.005$). Only (< 1%) of the farms in the study use disinfection (Footbath) to prevent any possible introduction of pathogens into the system. A detailed analysis of the various biosecurity measures and health management practices per county is shown in Fig. 6. There were no significant differences in the practices between the counties. For example, there were homogeneity in the regular removal of dead fish (Pearson Chi-Square test = 0.52, $p > 0.05$), fertilizer and liming (Pearson Chi-Square test = 4.11, $p > 0.05$) and water exchanges (Pearson Chi-Square test = 5.99, $p > 0.05$). There was no significant association between fish mortalities and fish health management practices and biosecurity measures (Fishers exact test, $p = 0.3348$).

### Common fish diseases and parasites in the three counties

The most recognizable disease by most farmers was the fungal infections, and other minor diseases such as cysts on the skin. Most farmers reported loss of scales, swollen scale, abnormal swimming activities, fin rots, and gulping for oxygen as common symptoms. Most of the diseases reported occurred during the rainy/cold season. The most commonly sighted parasite by the farmers is the leech (Hirudinea). In the present study, 60% of farmers would report incidences of sickness in the farm to the fisheries officers. There was no homogeneity between the three counties in terms of common fish diseases and parasites (Pearson Chi Square test = 180.748, $p < 0.005$).

## Discussion

This study revealed huge losses of fish through mortalities with most fish farmers not practicing biosecurity measures to prevent fish diseases and infections in the three counties probably due to a lack of awareness. It is widely accepted globally that many people have not given fish mortalities the attention it deserves as a fish welfare issue (Ellis et al. 2012). This was the first study focusing on groundtruthing of the fish health management and biosecurity measures in fish farms in Kenya.

### Source of water for fish farming in Western Kenya

Springs are the most preferred source of water in Western counties of Kenya because farmers consider the need to site farms in areas with permanent sources of water (Nguka et al. 2017). Besides being considered as a permanent water source, springs also have the best water

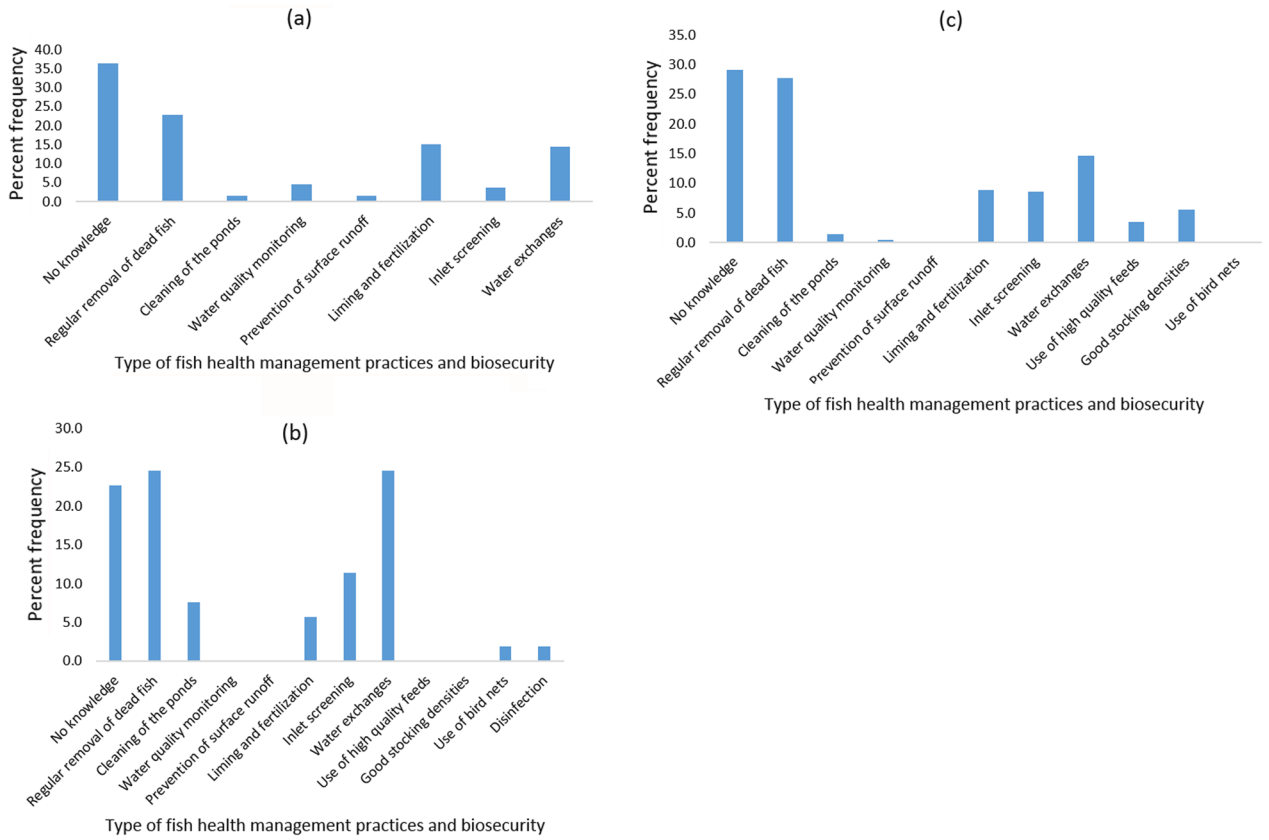


**Fig. 6** Showing the various biosecurity measures and fish health management practices in **a** Busia County, **b** Siaya County and **c** Kakamega counties. A: no knowledge on biosecurity, B: Regular removal of dead fish, C: Cleaning of the ponds, D: Monitoring of water quality, E: Prevention of surface runoff, F: Fertilization and liming, G: Screening at the inlet, H: Water exchanges, I: Use of quality feeds, J: Good stocking rates, K: Use of bird nets and L: Disinfection

quality with little or no known pathogens infecting fish. High water quality and its maintenance is considered a major mitigation against stress which predispose fish to diseases. Shitote et al. (2013) also reported the same results in Western Kenya. Other farmers (20%) rely on water from rivers for the fish farming operations. On the contrary farmers from the Central Kenya have been reported to use permanent rivers at 61% followed by public piped untreated water at 27% (Wanja et al. 2020).

### Common fish diseases and parasites in the three counties

It was noted generally that most fish farmers (76%) reported mortality in their hatcheries and farms with an overall loss of about 10%, but did not attribute the mortalities to fish diseases, hence seem to have accepted mortalities as being a normal occurrence. By extrapolation, for about 4500 fish farms in Kenya, then the total loss is 450MT, accounting for US $2.25Million in losses. Such high losses have been reported elsewhere. For example, in Brazil, a loss of up to US $84 million has been reported annually for about 16,100 fish farms (Tavares-Dias and Martins 2017). The most recognizable disease by most farmers was the fungal infections, and other minor diseases such as cysts on the skin. Most of the diseases reported occurred during the rainy/cold season. This is probably due to the fact that the two main fish species (Nile tilapia and African catfish) cultured in the region are warmwater species which thrive well in high temperatures, with deaths occurring at 12 °C (Ngugi et al. 2007). The most commonly sighted parasite by the farmers was the leech (Hirudinea). This finding is strikingly similar to that of Omasaki et al. (2013) in which leeches were also reported to be the common parasites infecting fish from the Counties of Kakamega, Kisii and Siaya.

### Biosecurity measures

A neglible percentage (< 2%) of the studied farms, for instance in Wakhungu Hatcheries in Busia County, did the study find the use of disinfection to prevent any possible introduction of pathogens into the system. This is very low as compared to other studies. For example, Faruk et al. (2012) reported that 76.66% of the hatcheries

in Bangladesh used disinfection of equipments as a biosecurity measure. This could be possibly due to a lack of awareness of importance. This challenge can have impacts which can be detrimental to the aquaculture sector, not only in the studied areas but also to the wider region given the transboundary trade in live fish. As indicated by Assefa and Abunna (2018), biosecurity measures are very critical in preventing entry of pathogens to farms.

With the global increase in aquaculture production, focus on biosecurity and fish health management is becoming increasingly important to meet the risks and impacts of aquatic diseases (Bondad-Reantaso et al. 2005). This is the first study focusing on fish health management and biosecurity measures in Kenya. The topic of fish health management, a significant input factor in modern fish farming seems to have undergone little scrutiny in the context of successful industry development in Sub-Saharan Africa (Børge 2018). The findings of this study on biosecurity are strikingly similar to the study in Uganda, which found a low level diseases knowledge and awareness, some basic biosecurity measures being carried out in hatchers, but very few or no basic biosecurity measures are implemented routinely in grow-out farms (Børge 2018). Aquaculture has been touted as a promising solution for food insecurity, poverty and malnutrition in Kenya (Ogello and Munguti 2016), and indeed the Government of Kenya continues to invest heavily towards the intensification of aquaculture. Unfortunately, in the recent times, some of the most infectious diseases which can cause serious losses in farmed fish, some up to 90% such as Tilapia Lake Virus (TiLV) (Matolla 2018), Infectious Pancreatic Necrosis (Mulei et al. 2018) and the Infectious Haematopoietic Necrosis Virus (IHNV) the causative agent of infectious haematopoietic necrosis, a disease of salmonid responsible for great economic losses (Mulei et al 2019) have all been reported infecting fish in Kenya and Uganda. It is important to note that the country's aquaculture production has been reported to be in a short fall of the required demand, hence imports such as those from China, and for us to have a true expansion in production, adequate fish health management is critical (Børge 2018). There are existing technologies in aquaculture including those of fish health management and biosecurity, however, there are gaps in technical skills, which hinder the uptake of those technologies and best management practices (Obiero et al. 2019). The most successful countries in terms of aquaculture production mainly in Asia and led by China have adequate fish health management systems and biosecurity measures (Mohammed and Subasinghe 2017). For example, with the onset of Tilapia Lake Virus (TiLV) outbreaks in several Asian countries, WorldFish in collaboration with Bangladesh's Department of Fisheries, has developed a program to improve biosecurity in the tilapia industry throughout the country (Mohammed and Subasinghe 2017).

## Conclusions

Western Kenya is one of the leading regions for aquaculture production in Kenya. This study concludes that there is a paucity of knowledge on fish health management systems and biosecurity measures, which presents a serious threat to aquaculture production in the studied counties and poses a great risk to trans-boundary live fish trade between Kenya and her neighbouring countries. Although fish farming is a promising area, it has had so many challenges among them high mortality rates. In China and other Asian countries, which are the world leaders in aquaculture production, they are making headway in fish health management and biosecurity. Lessons can be learnt from these countries and under the concept of Blue Economy development, the Kenyan government can develop aquaculture. Therefore, it will require collaborative efforts between the relevant ministry, departments and research institutions to formulate a strategy for the effective development, awareness creation, and implementation of the best fish health management practices and aquaculture biosecurity plans for the country (Additional files 1, 2 and 3).

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43170-022-00086-7.

**Additional file 1.** Fish health management questionnaire.

**Additional file 2.** Inferential statistics.

**Additional file 3.** Raw data file.

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#### Authors' contributions

DKM and ElO conceptualized the whole study and drafted the Manuscript. FA, ErO, KO, JA and CM participated in Data collection, data summarization and analysis and interpretation and edited the manuscript. JM: Supervised the study and edited the final copy. All authors read and approved the final manuscript.

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#### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on request.

## Declarations

### Ethics approval and consent to participate

The research was carried out under Ethics approval by the Egerton University Ethics Approval Committee.

### Consent for publication

All authors have consented to the publication.

### Competing interests

The authors declare that there are no conflict of interests.

### Author details

[1]Kenya Marine and Fisheries Research Institute, KMFRI Sagana Research Station, P.O. Box 451-10230, Sagana, Kenya. [2]Department of Biological Sciences, Egerton University, P.O. Box 536, Egerton, Kenya. [3]Present Address: Department of Fisheries and Natural Resources, Maseno University, Maseno, Kenya. [4]Kenya Marine and Fisheries Research Institute, KMFRI Sangoro Research Station, P.O. Box 136-40111, Pap Onditi, Kenya. [5]Kenya Marine and Fisheries Research Institute, KMFRI Kegati Research Station, P.O. Box 3259-40200, Kisii, Kenya.

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