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# The role of indigenous knowledge in fisheries resource management for aquaculture development: A case study of the Kenyan Lake Victoria region

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## Abstract

Indigenous knowledge is critical in the conservation of wild fish genetic resources and consequent development of fish seed for improved aquaculture production. Local fisher communities rely on aquatic resources mainly for livelihood and subsistence and have therefore come up with systems to manage these resources for sustainable use. This study aimed at identifying the role of indigenous people's knowledge in fish conservation as a way of improving aquaculture, with a specific focus on the conservation of aquaculture fish species in Kenya. Data was collected from individual fisherfolk through semi-structured questionnaires and field observations. Pearson's chi-square test was performed on variables that were predicted to influence indigenous knowledge. The chi-square tests revealed a significant relationship between age and indigenous knowledge ($\chi^2 = 15.153$, $p = 0.004$). Results also revealed a significant relationship between an individual's years of residence in the area and indigenous knowledge ($\chi^2 = 17.767$, $p = 0.003$). It was found that the indigenous people use various concepts and strategies for fish conservation and fish production. From the findings of the study, it is recommended that scientists and policy actors should adopt the indigenous people's knowledge as a source of baseline information for fisheries and aquaculture research, and as additional or alternative strategies for the management of fish genetic resources.

KEYWORDS
aquaculture, fish conservation, fish genetic resources, fisher communities, genetic diversity

## 1 | INTRODUCTION

Humans have depended on aquatic resources for centuries. Garcia-quijano (2010) points out how historical, archaeological and ethnographic information on the dependence on aquatic resources for subsistence has been crucial in the existence and well-being of human populations around the world. Local fishing communities rely on aquatic resources for a variety of reasons, including livelihood and subsistence. As a result, these communities have devised aquatic resource management and governance systems, resulting in resource sustainability and an interdependent link between people and resources (Hale et al., 1998).

Indigenous knowledge is the information that a group of people who live in a specific region have accumulated over time as a result of their experiences. Therefore, in their own culture, they have a grasp of their surroundings (Abah et al., 2015). Indigenous knowledge in the conservation of fish resources is useful in achieving continuous genetic diversity in fish because the local community involved in fishing activities has vast knowledge that can be exploited to gain the relevant information. Various scientific studies (Rim-Ruke et al., 2013; Rocliffe et al., 2020), have reported the importance of local-level knowledge in establishing fish populations and spawning areas, as well as controlling resource usage and traditions. In many nations across the globe, fish farmers have developed sustainable aquaculture techniques as a result of their use of indigenous technical knowledge, resulting in increased aquaculture production and improved livelihoods (Gangadhar et al., 2016).

The supply of fish and fisheries products has become unsustainable globally due to the increasing demand for fish (Aruho et al., 2018; Munguti et al., 2021b). Aquaculture that is considered the remedy for the overdependence on capture fisheries has thus been improved in recent years as an effort to meet the increasing fish demand (Béné & Friend, 2009). The efforts have been fruitful and in terms of global food production, aquaculture production can now be compared to production from capture fisheries (Ogello et al., 2014). The main producers of cultured fish are developing countries, accounting for approximately 90% of the total global aquaculture production (FAO, 2020). Kenya is among the countries that have seen a rapid rise in aquaculture over the past decade. Subsequently, the demand for quality fish seed has increased. As a result, both the government and the private sector have increased their investments in aquaculture production, increasing the number of fish seed producers of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarius gariepinus*) which are the most cultured fish species in the country (Nyonje et al., 2018). Production and supply of low-quality fish seed has been reported as a major challenge in the Kenyan aquaculture sector (Munguti et al., 2021a). Low-quality seed production has been attributed to lack of fish genetic management, which has resulted in deterioration in fish performance due to inbreeding, uncontrolled hybridization and genetic drift (Bostock et al., 2010).

The maintenance of fish genetic diversity is among the most important desired outcomes in the development of sustainable aquaculture production. Wild fish's genetic resources are valuable in aquaculture since they are free-living in their natural habitat and have had minimal disturbance by human activities (Roger, 2000). The wild relatives of cultured fish are important for use in breeding programmes as a source of genetic diversity. Conservation of wild fish genetic resources is therefore an important strategy for genetic management in aquaculture and it involves applying both scientific and the indigenous people's knowledge. Indigenous technological expertise is critical in the conservation of fish genetic resources and consequent development of fish seed for all farmed fish. Indigenous knowledge for sustainable management of aquatic resources has been acknowledged in Kenya's fisheries sector and rural development (Jabali et al., 2020; Manyala et al., 2001). Interactions between local community experts and scientists can be facilitated by a better understanding of indigenous knowledge systems. Indigenous knowledge can be a foundation of baseline data and can also provide resource managers and scientists with alternative strategies for the management of resources (Khamati, 2015).

Fishing, fish farming and fish use have been practiced by fisher communities around Lake Victoria in western Kenya for over five decades (Manyala & Ojuok, 2007; Ngugi et al., 2007; Ogutu-Ohwayo, 1990). As a result, they have a thorough knowledge and understanding of the various cultured freshwater fish species, as well as their breeding habits. Information on practices carried out by local fisher communities is a foundation for assessing their abilities and knowledge in the fisheries and aquaculture sector. However, there is insufficient documentation of the strategies and practices that the local people have come up with and implemented for the conservation of fish and subsequent improvement of aquaculture production in Kenya. The documentation of knowledge of the fisher communities in the Lake Victoria region is scanty, making it difficult for scientists and development practitioners to access it. There is therefore a need to document such information for effective use, as well as to make it readily available to researchers and other stakeholders for further scientific exploration. This study sought to bridge this knowledge gap.

## 2 | MATERIALS AND METHODS

### 2.1 | Study area

This study was conducted in six counties within the Kenyan part of Lake Victoria basin including Busia, Kakamega, Homabay, Kisumu, Migori and Siaya. In addition, the riparian and littoral areas (including river mouths) of Lake Victoria region, Kenya, were also surveyed (Figure 1). The counties have several rivers including Nzoia, Sondu-Miriu, Sio, Nyando, Kuja, Awach and Yala, and satellite lakes including Namboyo, Kanyaboli and Sare. These counties were purposively chosen for the study since they are occupied by fisher communities involved in fishing activities of freshwater fish. The region is occupied by two major ethnic communities: the Luo and the Luhya. The communities have had extensive knowledge of fisheries resources and their efficient use due to their dependence on the resources for livelihood.

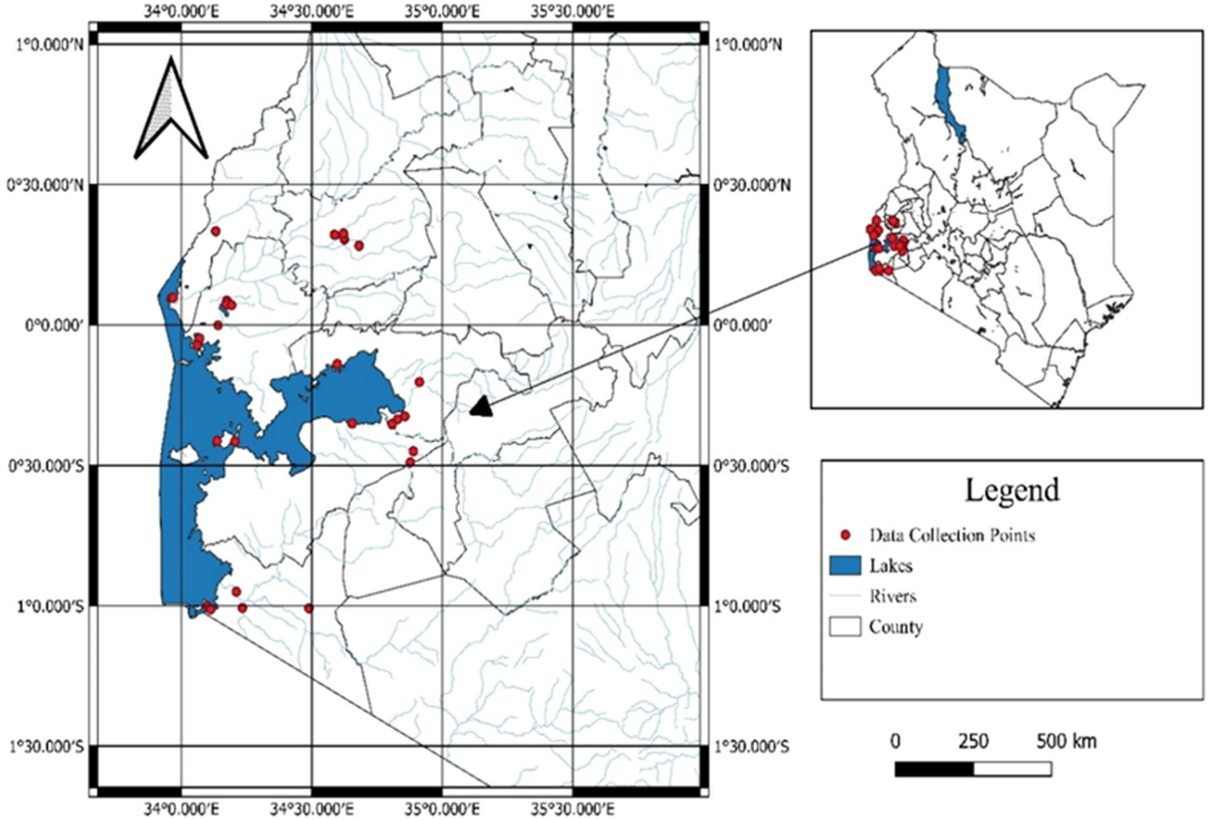


**FIGURE 1** Map showing the study sites in the Lake Victoria region.

### 2.2 | Data collection

Purposive sampling procedure was employed to select 100 fisherfolk as the study respondents. The study employed field observations and individual in-person interviews with the fisherfolk using a semi-structured questionnaire to collect the needed information. The questionnaire consisted of four key sections for capturing (i) demographic characteristics of the respondents, (ii) conservation of fish resources, (iii) knowledge of various aquaculture fish species, (iv) indigenous peoples' knowledge on fish farming. The questionnaire was pretested to get rid of any potential issues with time management, sophistication and applicability. Improvements on the questionnaire were then done based on the pretest feedback. The interviews were only conducted after getting consent from the respondents, expressing their willingness to be part of the study. All interviews were conducted in line with the World Health Organization (WHO) guidelines on COVID-19 prevention.

### 2.3 | Data analysis

IBM SPSS Version 25 programme was used to analyse the data. Pearson's chi-square tests wer conducted on variables that were predicted to influence the indigenous knowledge in fish resource conservation to determine whether there were significant relationships between indigenous knowledge and the various variables, at 5% significance level.

## 3 | RESULTS

### 3.1 | Demographic characteristics of the respondents

The characteristics of the respondents including age and the period of residence in the study area are shown in Table 1. Pearson's chi-square test revealed that age and the indigenous people's knowledge of fish resource conservation had a significant relationship ($\chi^2 = 15.153$, $p = 0.004$). The test also revealed a significant relationship between the individual's years of residence in the area and knowledge of fisheries resource conservation ($\chi^2 = 17.767$, $p = 0.003$).

### 3.2 | Indigenous knowledge of fish populations and breeding areas

The respondents reported that Nile tilapia (*O. niloticus*) was the dominant species in the study area. They also reported that the populations of most of the endemic fish species such as African carp (*Labeo victorianus*), Victoria tilapia (*Oreochromis variabilis*) and Singida tilapia

**TABLE 1** Demographic characteristics of the respondents.

| Characteristic | Frequency (*n*) | Per cent (%) |
|---|---|---|
| **Gender** | | |
| Male | 66 | 66 |
| Female | 34 | 34 |
| **Age distribution** | | |
| ≤25 | 5 | 5 |
| 26–35 | 25 | 25 |
| 36–50 | 35 | 35 |
| 51–60 | 18 | 18 |
| >60 | 17 | 17 |
| **Years of residence in the area** | | |
| 1–5 | 6 | 6 |
| 6–10 | 8 | 8 |
| 11–20 | 16 | 16 |
| 21–30 | 30 | 30 |
| 31–40 | 16 | 16 |
| >40 | 24 | 24 |

(*Oreochromis esculentus*) have reduced in Lake Victoria over the past decades but can still be found in rivers, dams and the satellite lakes around Lake Victoria. They reported that the reduction in populations of native fishes in the region was due to unsustainable fishing by some fisherfolk. This was brought about by overfishing and use of exploitative methods such as the use of herbs that caused massive fish kills, and exploitative fishing gear including prohibited gill nets and seine nets. They also attributed it to the increased predation by the carnivorous Nile perch (*Lates niloticus*).

The respondents also reported that fish mostly breed in river mouths and lagoons and are mainly found during rainy seasons as they move upstream. Additionally, some respondents reported traditional dugout trenches from which fish seed is collected. For example, clusters of various species of tilapia and catfish seed are collected at the estuary where river Nzoia enters Lake Victoria. Other breeding areas include the shorelines with papyrus reeds and muddy areas, and shallow shores near fish landing sites.

## 3.3 | Indigenous concepts and strategies used in the conservation of fish resources

Various concepts and strategies used by the fisher communities to aid in the conservation of fish species are shown in Figure 2. The indigenous people have come up with concepts and strategies such as restricting the species of fish to be caught to allow for conservation and regeneration of some species (restriction of species fished), use of traditional fishing gears that consider the size of fish caught (gear size regulation), closing off some areas from fishing activities (closed areas) and allowing fishing only during specific periods of the year (closed seasons). The other strategies reported include the implementation of rules and regulations formulated at the village level to ensure wise use of the resources from the rivers and lakes, and avoiding pollution of the lake by not draining wastewater into the lake which would lead to fish kills. The communities also conserve fish in dams and dig trenches along the rivers such that when it rains, the fish can swim against the direction of water moving downstream and are conserved in the trenches other than swimming into the lakes.

## 3.4 | Indigenous knowledge of freshwater aquaculture fish

The awareness of cultured fish and fish species with potential for freshwater aquaculture in the study area was gauged using a yes/no score, as shown in Figure 3. From the field observation and interviews, most of the indigenous people were aware of Nile tilapia (*O. niloticus*) (98%) and African catfish (*C. gariepinus*) (96%) as cultured species.

From the interviews with the local people in the study area, the two major inhabitant communities use different local names for the fish species (Table 2).

## 3.5 | Indigenous people's involvement in aquaculture

The study also assessed whether the indigenous people were involved in fish farming activities. Based on the field interviews, 21% of the respondents were involved in fish farming while the remaining 79% were not.

### 3.5.1 | Indigenous concepts and strategies used in aquaculture

As observed in the field, the fishers who are also involved in fish farming collect eggs and fry from the wild by laying common reed traps in the fish breeding areas mainly during rainy seasons (Figure 4). The fishers also collect mature Nile tilapia brooders from the wild for open pond rearing and subsequent fish multiplication. The brooders are selected based on their physical characteristics like size, strength in appearance and absence of deformities. This is done to ensure quality seed production. Identifying the sex of the fish is done by examining the genital papilla, body formation and body colour in Nile tilapia.

The fish are fed on worms, termites and leaves of food crops like sweet potatoes, kales and cassava. Duckweed (*Lemna minor*) is also used by some farmers to feed tilapia in their ponds. It was also observed that some of the seed producers use periphyton technology which is a traditional method for improving productivity in aquaculture by use of wood sticks driven into the muddy bottoms of their earthen ponds (Figure 5).

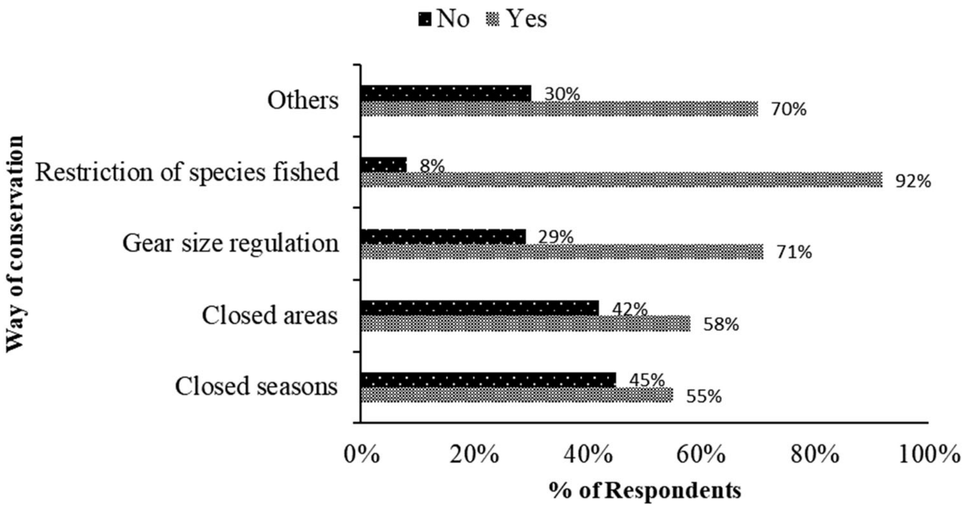


**FIGURE 2** Indigenous concepts and strategies used in the conservation of fish resources.

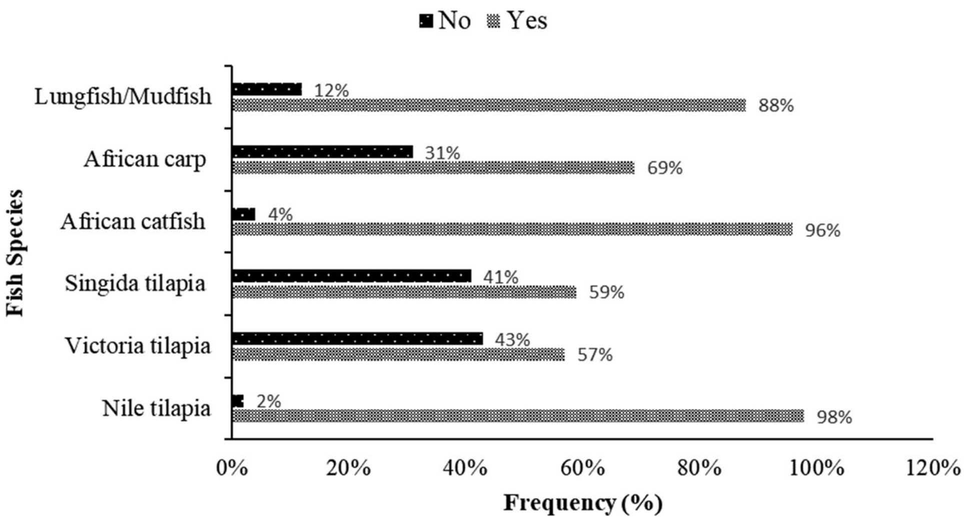


**FIGURE 3** Indigenous people's awareness of freshwater aquaculture fish.

**TABLE 2** Local names of various fish species identified by the indigenous people.

| English name | Scientific name | Local name | Family |
|---|---|---|---|
| Nile tilapia | *Oreochromis niloticus* | *Nyamami* (Luo), *Esotsi* (Luhya) | Cichlidae |
| Victoria tilapia | *Oreochromis variabilis* | *Mbiru* (Luo), *Imbuiru* (Luhya) | Cichlidae |
| Singida tilapia | *Oreochromis esculentus* | *Ngege* (Luo), *Ingeke* (Luhya) | Cichlidae |
| African catfish | *Clarias gariepinus* | *Mumi* (Luo), *Ituli* (Luhya) | Clariidae |
| African carp | *Labeo victorianus* | *Ningu* (Luo), *Eningu* (Luhya) | Cyprinidae |
| Lungfish/mudfish | *Protopterus aethiopicus* | *Kamongo* (Luo), *Imonye* (Luhya) | Lepidosirenidae |

## 4 | DISCUSSION

The indigenous people's age and their years of residence in a particular environment are a good measure of their understanding of the resources in their environment (Khamati, 2015). To examine indigenous knowledge on fish conservation, the age of the persons and their years of engagement with the resources are crucial factors. This study's findings show a strong relationship between the indigenous people's age and their knowledge of fish conservation. The elderly members of the fisher communities have more knowledge about the different fish

**FIGURE 4** Common reed traps laid for seed and broodstock collection in Lake Victoria.

**FIGURE 5** Wood sticks used for periphyton technology in an earthen pond.

species and their conservation in the natural habitat than the younger members of the communities. Jabali et al. (2020) also found that a person's age is a determinant of how long they have been interacting with the natural resources and determines how much knowledge they have gathered about the resources over time.

Among the cultured freshwater fish species, *O. niloticus* was found to be the most dominant in Lake Victoria and this is attributed to the over-exploitation of the endemic tilapiine species which has led to reduced competition. *O. niloticus* is most abundant in areas rich in algae and primarily feeds on phytoplankton. The findings of this study are consistent with those of Goudswaard et al. (2002) and Balirwa et al. (2003) who found that *O. esculentus* and *O. variabilis* have been driven to extinction or genetically integrated by the flourishing *O. niloticus* which forms the major component of fisheries in L. Victoria. Predation by Nile perch (*L. niloticus*) which was introduced into the lake also largely contributed to the reduction in populations of the native fish species (Achieng, 1990). An example is the competition with catfish which came up when exotic *L. niloticus* were introduced into L. Victoria in the 1950s and 1960s, causing the extinction of local catfish species due to high competition and predation levels (Barasa et al., 2014). The population reduction and extinction of a number of the native species such as *O. esculentus* and *O. variabilis* were further worsened by the use of destructive fishing methods and gear. Human intrusion and infringement also destroyed breeding grounds. Additionally, the lake's water quality has worsened over the years, owing primarily to eutrophication, which is caused by increased nutrient load in the lake (Mwamburi et al., 2020).

The shallow inshore areas of Lake Victoria which are <5 m deep are considered to be important breeding, nursery and feeding grounds for various fish species (Aura et al., 2019). Fisher communities identified fish breeding grounds as the areas along the shores with vegetation like papyrus and common reeds, muddy areas and shallow shores near landing sites and lagoons, and river mouths, which relate with the studies from Lake Chilwa, Malawi, that found that the river mouths and other areas like lagoons are breeding areas for fish (Kabwazi & Wilson, 1998).

The present study established that the indigenous people have come up with concepts and strategies which are used in the conservation of fish for improved genetic diversity. The local fishing gears are made based on a thorough understanding of the fish habitats and the topography of the water bodies. In terms of restriction of gear size and fish species fished, the communities use bamboo, common reed and basket fish traps, considering the size of the targeted fish. This is done to avoid catching small immature fish hence promoting fish conservation by ensuring that fish are left to grow to maturity. There was an introduction of closed seasons by the indigenous people, during which no fishing activities were allowed in the lake, giving room for fish to reproduce and increase in numbers. During the closed season, there was a restriction by the elders and clan leaders on the areas where the fishing boats and canoes could access. The fisher communities also have protected areas, restricting fishing along the shores and in fish breeding areas. A similar finding was reported by Bokea and Ikiara (2000), where the local fishing communities were found to have their regulations on fishing activities like the restriction of fishing gear that ensured that only the right fish sizes were caught and overexploitation was avoided to ensure the sustainability of the fishing industry.

In the present study, the fisherfolk reported that they use appearance, colour, breeding areas, body stripes and scales, among other features to identify and distinguish different fish species. These findings are consistent with those of Granadeiro and Silva (2000) which reported that fish colour patterns, their difference in shape, size and count of scales, otoliths, difference in body size and the difference in size and types of their fins, as external morphological traits, have traditionally been used in the identification of fish species. The current study also found that the indigenous people of the Kenyan Lake Victoria region are mostly aware of *O. niloticus* and *C. gariepinus* as the main cultured fish. This justifies the reason why Kenyan warm water aquaculture is dominated by the farming of the two species (Opiyo et al., 2018). Despite having the potential, the culture of indigenous fish species like *L. victorianus*, *O. esculentus* and *O. variabilis* has not been widely adopted by farmers because of their low production levels and survival (Munguti et al., 2014; Orina et al., 2018).

The involvement of the indigenous communities in fish farming is important in the maintenance of fish genetic resources which is a major concern in aquaculture development. The fish get to multiply naturally, without alterations in their genetic component since the indigenous people do not use technologies that would compromise their genetic integrity (Araki, 2008). According to the findings of current study, the fisherfolk who are also involved in fish farming collect eggs and fry from the wild by laying common reed traps in the fish breeding areas mainly during rainy seasons. Kalita et al. (2004) also reported similar findings of fish seed collection from the wild, reporting that fishers in Assam hills in India collected seed of *murrels* which move in shoals and come near the water surface for air, making them easy to collect. The earliest means of collecting fish broodstock was the harvesting of eggs and fry from the wild and this is still going on for species for which a large number of fry are readily available in the wild (Meshram et al., 2009). However, there are risks associated with collecting fish seed from the wild. These include lack of uniformity in fish sizes and lack of knowledge of their age, and the seed could be of poor quality and could carry diseases (Mwainge et al., 2021; Nyonje et al., 2018). This implies that seed collected from the wild should be quarantined and properly screened for diseases to avoid introducing diseases into the farm (Opiyo et al., 2018). The Kenyan State Department of Fisheries has provided guidelines and protocols to be followed when collecting seed from the wild (GoK, 2015). To ensure fish productivity, our findings revealed that the indigenous people that rear fish use traditional methods of predator control like applying herbs and cow dung around ponds to prevent predators like snakes and monitor lizards. They also use aquatic macrophytes such as duckweed (*Lemna minor*) as fish feed in their dugout ponds, and periphyton technology. Duckweed, which has been found to have a very high nutritional value for fish (Saber et al., 2004), is used by some of the farmers to feed tilapia in their ponds. Periphyton technology is a method that has been effectively used for tilapia production (Gangadhar et al., 2016). The method uses substrates such as wood sticks and bamboo sticks in earthen ponds. Periphytons are rich in nutrients that can be used by fish to increase their growth and productivity (Abwao et al., 2014). The technology is also useful in maintaining good water quality by helping in the conversion of ammonia into microorganisms which are also a source of protein for fish (Ogello et al., 2014).

## 5 | CONCLUSION AND RECOMMENDATIONS

The study aimed at understanding the role of indigenous people's knowledge of fish conservation for the improvement of aquaculture through sustained genetic diversity. The study found that the fisher communities in the study area have established and maintained some indigenous knowledge and practices that are important in the management of fisheries resources. For example, the indigenous people's strategies like protection of fish breeding areas by restricting fishing gear help in ensuring young fish are not caught and fish spawning areas are not destroyed. The collection of wild fish as the stock material for aquaculture production also helps in conserving fish genetic resources and ensures genetic diversity.

This study recommends the uptake of indigenous people's knowledge by scientists as a source of baseline information for fisheries and aquaculture research. The indigenous knowledge also needs to be adopted as additional or alternative strategies for the management of fish genetic resources for improved aquaculture production.

## AUTHOR CONTRIBUTIONS

**Kevin Odhiambo Obiero**: Conceptualisation; Formal analysis; Methodology; Writing–original draft. **Jimmy Brian Mboya**: Formal analysis; Investigation; Writing–original draft. **Kevin Okoth Ouko**: Formal analysis; Writing–original draft. **Elijah Migiro Kembenya**: Investigation; Methodology; Supervision; Validation. **Elizabeth Akinyi Nyauchi**: Investigation; Visualisation; Writing–review & editing. **Jonathan Mbonge Munguti**: Conceptualisation; Formal analysis; Methodology; Writing–review & editing. **Nicholas Otieno Outa**: Investigation; Visualisation. **Cecilia Muthoni Githukia**: Investigation; Methodology; Supervision; Validation.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest that might arise as a result of the publication of this article and the information therein.

## DATA AVAILABILITY STATEMENT

We certify that the data used in this article were collected from the study and can only be availed through the request and permission of the third-party authors.

## ETHICS STATEMENT

The study was conducted within the scope of Kenya Marine and Fisheries Research Institute's (KMFRI's) ethical provisions. The institute is mandated to conduct studies on fisheries and aquaculture in the country and abides by the KMFRI Research Policy and the KMFRI Social Science Research Ethics.

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## PEER REVIEW

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