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Low-input cage culture: towards food security and livelihood improvement in rural Kenya

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Summary

Recent experiences and successes including the dwindling capture fisheries and global increase in aquaculture production have spurred interest in the development of commercial cage culture in Africa. This case study centres on cage culture of tilapia in Kenyan waters of Lake Victoria and in satellite dams within Lake Victoria's catchment. It reports on unique challenges and the innovative ways in which Kenyan fish farmers and fishers have had to undertake to ensure success. Increased public concern and suspicion on the long-term environmental and ecological sustainability of cage-based farming systems in the lake has been a major area of concern. This study presents ways in which farmers and researchers have managed to rear caged fish with low input fish food and feed, provide quality fish seed, use locally available materials for making cages and ensure cage security. Cage culture can be beneficial in the Lake Victoria basin as emerging constraints are resolved.

Background

General history of cage culture

Cage culture of fish and other aquatic organisms dates back to the 1800s and was first reported in the Yangtze River delta in China (Coche, 1982; Hu, 1994) from where it spread to Cambodia and Indonesia in the late 19th and early 20th centuries (Hickling, 1962; Ling, 1977). In Africa, large-scale cage culture was first carried out in Ivory Coast in 1974 in Lake Kossou with Oreochromis niloticus (Coche, 1974) and in Lake Victoria, Tanzania with Tilapia zilli (Ibrahim et al., 1974). In response to dwindling stocks of Lake Kivu, the 'Pecheurs de Lac Kivu' Cooperative initiated cage farming of tilapia in Lake Kivu, Rwanda around the same time. Although these early attempts were not successful, recent events and successes in the development of commercial cage culture in Africa have spurred new interest. Climate and ecological changes, over-fishing, ecosystem degradation and the resultant dwindling capture fisheries together with the rising fortunes of aquaculture has led many to turn to aquaculture in general and cage culture in particular.

In Kariba dam, at the border of Zambia and Zimbabwe, success has been reported for large- and small-scale cage culture of tilapia and carps (Gabriel, 1991; Fölster, 1994). Each year, Lake Kariba produces 2000-4000 tonnes of caged fish. One of the major producers is Lake Harvest Aquaculture (Pvt) Ltd (http://www.lakeharvest.com/). Lake Harvest fish farm was formed in 1997 and is located on Lake Kariba, Zimbabwe. It was formed to process and market tilapia for international markets especially in Europe and thus their fish products comply with EU standards and HACCP system [see the case study in this Compendium; 'Case study: commercial production of Nile tilapia on Lake Kariba, Zimbabwe'].

Bolstered by the successes in Lake Kariba, fishers in Lake Victoria are turning to cage culture, which is expected to offer alternative livelihoods to fishing and at the same time utilize the large expanse of the now under stocked waters left behind by the dwindling capture fisheries in the face of climate and ecological changes, ecosystem degradation as well as overfishing. Water-based systems such as cage and pen culture, enhanced fisheries in large and small communal water bodies, may be the only options for aquaculture for the landless and underemployed fishers (Edwards, 2000). Although cheaper than ponds, it is worth noting that setting up even small cage farming sites requires capital for cage materials, equipment, boat, and commercial feed. Although cage farming has been mostly a necessity for fishers in small water bodies, it has become necessary for fishers in large lakes as well.

Advantages of fish cage farming

The advantages of cage culture over other culture systems include the ability to utilise many types of water resources such as lakes, reservoirs, ponds and rivers, which would otherwise be unsuitable for fish farming due to difficulties in harvesting (Masser, 1991). Apart from this, cage culture, if using existing water bodies, requires relatively low initial investment compared with the cost of land based pond or tank construction (McGinty and Rakocy, 1989). Cages can support high stocking densities while at the same time preventing occurrence of a build-up of waste metabolites inside the cage, due to a continuous water exchange (FAO, 1978). Using floating cages facilitates the culture of mixed sex stocks for precocious breeders like tilapia without reducing the growth rate of females because it disrupts breeding as lacking their normal pond bottom substrate the females are unable to build nests. Thus, cage culture can minimise one of the biggest problems of tilapia culture in other systems like ponds. Due to high density and limited space, cages also limit fish movement thus reducing the amount of energy required for muscle activity and, in turn, lead to increased growth. Furthermore, cages make it easy to control fish predators. Cages can also be moved to different locations in same water body and are less prone to theft than land based farms. In permanent water bodies, cage culture allows for a steady and often well mixed supply of water throughout the growth period. Compared with ponds, harvesting of fish, handling or grading of fish is relatively easier as nets just need to be lifted.

Challenges associated with cage culture

Cage aquaculture provides a number of challenges associated with the environment, theft of fish and cage destruction due to bad weather. Due to the rich protein diets fed to caged fish, the surrounding water might have a high nutrient load due to uneaten feed, faecal waste and excreta from cage-reared fish. This could have serious impacts upon water quality in the cages and in the surrounding water, leading to deterioration in ecosystem health (Mente et al., 2006). Deterioration in water quality, together with higher stocking densities, can lead to increased risk of disease occurrence among cage reared fish (Chen et al., 2007) and the potential risk of transfer of fish diseases to natural populations. The risk is made more serious because of the difficulty of treating fish in cages compared to land-based pond or tank systems. Fish escapes may occur from cages due to breakages of the netting material, cage destruction by wild aquatic animals such as hippos, otters or crocodiles, or inadvertently while sampling. Fish escapes may have negative or positive impacts on wild fish populations, through genetic contamination, induced ecological changes and social or behavioural impacts (FAO, 2006; Ferguson et al., 2007; Hindar et al., 2006; Soto et al., 2001).

Other challenges or potential problems with cage culture include the removal of fish mortalities and wastes. This can be a serious problem unless cage design has a proper mortalities ‘sock’ or trap for regularly removing dead fish from the bottom of cage. Cage culture requires certain depth of water to be feasible and sustainable and adequate flow or water exchange to enable removal of wastes and maintain good water quality. This makes cage culture to be suitable mostly in deep water bodies or in flowing waters. Apart from this, cage culture has issues with potential safety of employees. Compared to land sites – the cage culture working environment can be dangerous particularly in bad weather such as when it is windy and stormy. Proper cage design can minimise this risk.

Cage designs and implications

The design of fish cages is determined by several factors. In designing a cage it is important to ensure that the fish and the people who use the cage are safe as mentioned above. The parts of a floating cage unit should be designed and constructed in a manner that provides suitable anchorage, buoyancy, strength and stability. When deciding on the adequacy of these features it is necessary to take into account the likely loads imposed by vehicles, equipment, fish food, etc., and the effect of waves and wind. Continued safety of the installation will depend on regular routine inspection combined with maintenance inspection, normally at least once a year and immediately after storms (HSE, 1997). Lack of proper maintenance can lead to serious losses of fish, property or human life.

Both floating surface and standing surface cages are used. Standing cages are tied to stakes driven into the bottom of the substrate, whereas floating cages require a floatation device to stay at the surface. Floatation can be provided by metal or plastic drums, sealed PVC pipe or Styrofoam and similar materials. Cages should be constructed from materials that are durable, light-weight and inexpensive, such as galvanized and plastic coated welded wire mesh, plastic netting and nylon netting. Welded wire mesh is durable, rigid, more resistant to biological fouling and easier to clean than flexible material but it is relatively heavy and cumbersome. Plastic netting is durable, semi-rigid, light-weight and less expensive than wire mesh cages made of nylon netting. Nylon mesh is inexpensive, moderately durable, lightweight and easy to handle. However, nylon is susceptible to damage from predators such as turtles, otters, alligators and crabs. Therefore McGinty and Rakocy (1989) suggested an additional cage of larger mesh and stronger twine would be suitable around nylon cages.

Cage sizes may vary from 1 to 1000 m^3 (McGinty and Rakocy, 1989). However, cage handling is a challenge and labour intensive and at times requires complicated machinery.

Therefore, for small-scale cage culture small, easy to handle cages are necessary in order to overcome the challenge of handling and to minimize labour (Waidbacher et al., 2006).

Cage mesh size has a significant impact on fish production (McGinty and Rakocy, 1989). The choice of cage mesh size for use in any water reservoir for optimum production is a major challenge because while the net mesh should not allow fish to escape, it should not be too small as to prevent water exchange and compromise water quality in the cage; smaller mesh sizes also require more regular cleaning and maintenance. Larger mesh size facilitates good water circulation through the cage to renew supply of oxygen and removal of metabolites. However, larger mesh size may allow the cultured fish to escape from the cage and/or allow wild fish to enter the cage. Cages with mesh sizes of between 13 and 19 mm (0.5 and 0.75 inches) are recommended for cage culture of tilapia (Masser, 1988) and other fish of the same size. These mesh sizes provide open space for good water circulation through the cage to renew the oxygen supply and remove waste, which is a key tool for the success of tilapia cage culture.

Description

This case study centres on cage culture of tilapia in Kenyan waters of Lake Victoria and in satellite dams within the Lake Victoria catchment area. It reports on unique challenges and the innovative ways in which Kenyan fish farmers and fishers have undertaken to ensure success in cage culture.

The Kenya Marine and Fisheries Research Institute (KMFRI, http://www.kmfri.co.ke/) and Lake Basin Development Authority (LBDA, http://www.regional-dev.go.ke/lbda/index.htm) are carrying out a series of experiments to collect data on the environmental and socioeconomic impacts of cage farming in Lake Victoria waters. Cage culture in small water bodies has been carried out over the last three years on an experimental basis in the Lake Victoria region and elsewhere in Kenya, Uganda and Ethiopia through a consortium known as Bomosa (http://bomosa.oeaw.ac.at/). Bomosa is a consortium including KMFRI's Sangoro Aquaculture Research and Development station (http://www.kmfri.co.ke/), Universität für Bodenkultur Wien (http://www.boku.ac.at/), Moi University (http://www.mu.ac.ke/), Austrian Academy of Sciences (http://www.oeaw.ac.at/english/home.html), University of Bologna (http://www.eng.unibo.it/PortaleEn/default.htm), Enki public benefit cooperation (http://www.ist-world.org/), Ministry of Fisheries Development, Kenya (http://www.fisheries.go.ke/), Egerton University (http://www.egerton.ac.ke/), Ethiopian Institute of Agricultural Research (http://www.eiar.gov.et/) and Department of Fisheries Resources Uganda (http://www.ugandafish.org/default.htm). We report on the developments in this project "Integrating BOMOSA cage fish farming system in reservoirs, ponds and temporary water bodies in Eastern Africa" (http://bomosa.oeaw.ac.at/).

Through these projects and farmer experiences it has become clear that apart from the challenges mentioned above, efforts to develop cage culture in Kenya are hampered by several unique factors. These include lack of appropriate fish feeds, menace of hippos, monitor lizards and crocodiles, lack of proper materials for cage construction and lack of a national aquaculture policy, also a national policy, which has any specific strategies or plans related to development of cage culture. Increased public concern and suspicion on the long-term environmental and ecological sustainability of cage-based farming systems in the lake has been a major area of concern. Below are some of the issues and mitigations by Kenyan cage fish farmers and research organizations.

Feeds

Appropriate fish feeds for caged culture are not available in the country. Such feeds should ideally be floating feeds to allow the fish time to fully consume the feeds. In small water bodies, farmers feed their fish at only designated times when fish are hungry so that all the feed can be consumed. To tackle the problem of lack of fish feeds, fishers turned fish farmers in Lake Victoria do not feed their caged tilapia fish but depend on use productivity of the lake's eutrophic waters. Although under normal circumstances, lack of feeding would mean longer rearing period before reaching table size, the Lake Victoria waters are quite productive enabling growth of Nile tilapia and other planktivorous species. Table 1 shows that the water quality and productivity parameters in one of the cage sites are good for fish growth and that the water circulation is high.

Table showing temperature, conductivity, chlorophyll A and dissolved oxygen at different depths in a cage site in Lake Victoria

Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Chlorophyll A (µg/l)	Dissolved Oxygen (mg/l)
<1	27.1±0.11	105.4±0.19	24.5±4.33	8.1±0.14
1-2	26.7±0.27	105.4±0.17	43.7±12.38	8.0±0.13
2-3	26.5±0.24	105.3±0.10	36.3±9.14	8.0±0.06
3-4	26.1±0.06	105.5±0.14	43.3±5.04	7.9±0.05
>4	26.0±0.04	104.4±1.53	38.5±4.20	8.0±0.10

The Bomosa cage culture project "Integrating BOMOSA cage fish farming system in reservoirs, ponds and temporary water bodies in Eastern Africa" (http://bomosa.oeaw.ac.at/) has, as one of its most important components, a work package dealing with provision of appropriate fish feeds for cage culture in small water bodies. Tables 2 and 3 indicate the proximate composition of the feedstuffs and percent inclusion of the feed ingredients used for production of formulated diets for the caged fish. These diets are made from locally available fish feeds, which make them inexpensive for the local fish farmers. The Bomosa cage culture project has so far been carried out in small water bodies - mainly dams and impoundments - but not in the Lake Victoria proper. Table 2 shows some of the water quality parameters from one of the Bomosa sites, Harambee Dam, in Western Kenya.

Table showing temperature, dissolved oxygen (DO) conductivity, pH, and salinity at different depths at a cage site in Harambee Dam, Victoria Kenya (latitude 0°18'54.7", longitude 034°53'45.4" and altitude 1175.6 m).

	Water quality variable		
Parameter	**Max**	**Min**	**Mean±SD**
Temperature	27.23	23.09	23.96±0.73
DO (mg/L)	8.38	0.28	
Conductivity (µSm/cm)	270	247	250±2.0
pH	9.06	7.4	8.24±0.23
Salinity	0.13	0.12	0.12±0.0006

Harambee dam is approximately one acre with an average depth of 2 m. Thus this water body has a potential to support larger numbers of cages. Initially owned by the surrounding community, its management and control was later taken over since 2005 by Nyadec (Environmental Conservation Network) http://nyadec.org/, a Community based Environmental NGO. The NGO is run through trust members who are comprised of 40 members. The dam is permanent and water supplied through run-off and apart from tilapia cage culture, which began in 2007, the water is used for watering cows, washing clothes, and watering tree nurseries.

Fish growth in Bomosa cages: the case of Harambee dam, Nyanza, Kenya

Male tilapias are stocked at average stocking weight of 20 g (KMFRI Sangoro aquaculture station at a density of 130 fish/cage. At harvest, the fish have an average of 285 g bodyweight after 7 months of growth. The cage is 0.64 m3, which indicates a stocking density of 203 fish m-3. From 10 cages at Harambee and a stocking of 1300 fish, about 1200 fish are harvested with a weight of over 340 kg.

Each cage is made up of two rectangular frames, which form the top (1.2 x 0.94m) and base (0.9 x 0.9m) of the cage. The frames of the cages are constructed from 5.1-cm diameter polyvinyl chloride (PVC) pipes and covered with nylon net with mesh a size of 1.4 cm. The cage has a height of 0.75 m when submerged in water, with a slight constriction at 0.4 m below the upper frame, and displacing a volume 0.64 m3. The tubing of the upper frame is completely sealed to offer a self-floatation mechanism, while the lower frame is open through two T-joints of 5.1-cm diameter on the opposing sides of the frame. These openings allow the lower frame to sink. Therefore, the cage does not require external devices to aid in either floatation or sinking (Waidbacher et al., 2006). Harambee Dam is owned by the community around it and a committee of 40 people look after it of whom 20 are female and about 10 are youths. The group has employed a manager, Mr. Elly Kitoto, who manages the day-to-day running of the fish farm. Upon harvest, the fish are sold in the local market with limited fish given to community group members. Because there is no electric power at the premises, the fish are stored live in a large storage cage until all fish are sold. The original cages were purchased by the EU through the BOMOSA project. However, platform repair and subsequent feeding of fish is the responsibility of the community.

Given that only 10 cages are used at the moment, leading to a harvest of over 340 kg of fish, it is clear that a further increase in the number of cages could have a significant impact on the cage farming community.

Table showing the approximate composition of the feedstuffs used in diet formulation (as-fed basis)

Ingredient[a)]	Nutrient[b)], %					
	DM	CP	EE	CF	NfE	Ash
FSM	87.5	60.3	1.4	6.2	6.7	24.8
CSC	89.8	34.9	12.8	25.8	19.4	6.0
WB	88.0	14.0	5.9	13.6	60.2	6.3

a)FSM = freshwater shrimp meal; CSC = cotton seed cake; WB = wheat bran
b)DM = dry matter, CP = crude protein, EE = ether extracts, CF = crude fibre, NfE = nitrogen-free extracts

Table showing the percentage composition of feed ingredients in the formulated diet

Ingredient	% Ingredient inclusion	% Protein contribution	% Lipid	% Crude fibre
Freshwater shrimps	12.0	7.6	0.7	0.5
Cotton seed cake	44.4	15.9	3.0	3.2
Wheat bran	43.6	6.1	2.8	7.0
Total	**100.0**	**29.6**	**6.5**	**10.6**

Cages were fed at 6% body mass using locally fabricated automated spring feeders, the feeds are formulated and prepared at Kenya Marine and Fisheries Research Institute (KMFRI), Sangoro Aquaculture station, using an ordinary meat mincer. Thte table shows an example of the feed ingredients used to produce the feeds. By pelletizing and drying the feeds, it is possible to produce semi-floating feeds that enable fish to consume them before they sink to the bottom of the cage.

Lack of quality fingerlings

Compared to pond stocking, larger fingerlings are required for cages because they should be large enough to be retained in the cage nets. While ponds can accept fingerlings that are as small as 1 g in bodyweight, fingerlings for cages must be over 20 g to ensure that there are no losses through the net mesh. One of the major constraints to fish farmers in the region is the lack of quality fish seed. For cage culture, this challenge is compounded by the fact that most fingerling production units would rather sell their fingerlings when they are still small to avoid extra expenses of feed and rearing unit space. Since most hatcheries do not adhere to genetic principles in breeding of their fish, growth is often curtailed by effects of inbreeding, increasing feed conversion ratios and thus greater utilization of fish feed. Furthermore, while ordinary tilapia fingerlings (1-5 g) are sold from 3 K Sh, tilapia seed suitable for cage culture (20-30 g) are sold at 5-8 K Sh, indicating that the extra efforts at increased growth do not translate into monetary gain. Coupled with a tremendous increase in the demand for fingerlings for aquaculture throughout the region, this makes hatcheries not to see any motivation in growing fish seed to larger sizes. Thus farmers have learnt to rely mostly on the government hatcheries that produce fingerlings for cage culture. To ease the problem of poor quality seed, a project 'Selective Fish Breeding for Quality Seed to Enhance Aquaculture Production in Kenya' has been going on since 2006 with funding by the government of Kenya. The aim of the project is to provide fast growing and high yielding quality seed of Clarias gariepinus and Oreochromis niloticus to farmers. Although all male tilapia are preferred for their fast growth, it is not entirely necessary to use all male tilapia in cages. It is enough to use good quality mixed sex fish because cage culture disrupts the precocious breeding common with pond reproduction.

Hippo and crocodile menace

The presence of hippos and crocodiles, and in some instances monitor lizards, in the inshore areas of Lake Victoria, which tear into cage nets and destroy cage frames has made it necessary for farmers to redesign their cages. The cage redesigning includes fixing spokes to scare the animals away. Alternatively, hippos and monitor lizards are kept at bay be using wire mesh spokes.

Lack of cage materials

Materials for cage frames, cage nets and piers are commercially unavailable in the country. Also, importation has been an expensive option because of high taxes and legal requirements by the government that importers adhere to fish mesh sizes suitable for proper management of capture fisheries. This makes imported nets expensive and out of reach for many rural fish farmers. Nevertheless, imported nets, which are specifically made for cages are much more durable. Farmers therefore have to improvise by making their own nets from twine of between 42-45 ply, which are sold locally. Through the Aquaculture Association of Kenya, which brings together fish farmers from different parts of the country, farmers have begun to lobby the Kenyan government for tax reduction on essential implements including cage materials. Recently, Monasa Nets (Kenya) Limited in Kisumu (for details contact: Miraly Nasrulah, PO Box 9473, Kisumu, Kenya; email: cabnibasa@swuftjusyny.cin) has begun stocking nets suitable for cage culture, which may ease the increasing demand.

Public concerns of cage farming in large water bodies

Cage culture in Lake Victoria has elicited deep reactions for and against it. Being a shared lake, conflicts have arisen among the East African countries on whether to venture into cage culture in the lake. Those for cage culture in the lake point to the fact that with the dwindling fishery, the large expanse of water could be more aptly used for fish production through cage farming, which would alleviate poverty and contribute towards food security. However, those against the venture point out that conservation of the fish species and maintenance of environmental integrity of the lake overrides any gains that may be realised through cage aquaculture in Lake Victoria. To ensure that cage farming in the lake is carried out without raising outcry from environmentalist, Kenyan farmers avoid using high input feeds and prefer allowing the fish to feed on naturally available food. Consequently, fish are stocked at lower densities of about 100 fingerlings m-3 allowing the fishers turned farmers to obtain alternative fish sources at a modest price. From this modest stocking density, farmers have reported yields of between 14-16 kg m-3 at 150-200 g body weight in 4-6 months. Although the resultant production is lower than in intensive tilapia cage culture systems which report yields of up to 330 kg m-3 at 500 g in four months (Rojas and Wadsworth, 2007), cage culture in unfed cages is cheaper, more environmentally friendly and is still much higher than production from ponds.

Lack of aquaculture policy

Although aquaculture has been recognized by the government of Kenya as an important sector for development, the sub-sector has operated without a comprehensive aquaculture policy since independence. Cage culture in public waters therefore has had to develop in an environment of uncertainty since its legal status is not well defined. This has led to lack of focussed development and hampered cage culture activities due to conflicts with other environmental bylaws. Thus farmers have experienced difficulties in obtaining the necessary legal backing. To ease these problems, farmers have been lobbying and participating in stakeholder meetings with government officials to ensure that cage culture is recognised, captured in aquaculture strategic plan documents and facilitated as a major contributor to fish production in the country. As a result, a Fisheries Policy has been approved for implementation and an aquaculture development strategy is under preparation.

Cage security

One of the problems in cage farming can be theft of fish and cage materials. Cage farming has experienced security problems due to the poverty levels among the rural populace in the Lake Victoria region. It is normal for whole cages to be stolen at night. To prevent this, Beach Management Units - community-based organizations that are legally accepted representatives of fishing communities regarding fisheries resource utilization and management – have established committees to manage the affairs of the cage culture venture and ensure 24-h surveillance. Organized communities and community surveillance is key to success of the cage culture because it ensures ownership of the projects.

The experience of Obenge Beach, Lake Victoria, cage fish farmers

Fishermen from Lake Victoria have over the years experienced serious declines in fish catches. The dwindling capture fishery in the country has led to decline in the livelihood of fishers making it necessary to find alternative sources of livelihood. The Obenge Beach Management Unit (BMU) http://www.growfish.com.au/content.asp?contentid=12052 is one of the community-based organizations which manage the utilization and conservation of the lake's resources and operates around the Obenge beach area. Building from their experience with water and fish, the fishers belonging to Obenge BMU asked for help to start a cage culture project. A cage culture project was started in 2007 enabling them to supplement their catches. About 20 mostly youth of Obenge BMU members are fully involved in the day to day operations of the cages. At the same time, they continue to engage in other fishing activities.

Due to public concerns about the use of fishmeal -based fish diets, the project started on an experimental basis to collect data on environmental effects and social acceptability of cage culture. Preliminary results showed that the eutrophied waters of Lake Victoria had sufficient productivity to support caged fish. Therefore, fishermen who are turning to farming do not feed their fish at all but depend on natural occurring plankton. The Kenya Marine and Fisheries Research Institute (KMFRI) Sangoro staff are spearheading research into the environmental effects of addition of pelleted feed. KMFRI provides BMU with fingerlings of Nile tilapia and Ngege (Oreochromis esculentus) for stocking free of charge and the farmers take care of the cages by removing mortalities and ensuring cage safety. The fish cages are usually accessed through boats owned by the fish farmers. Fingerlings are stocked at between 20 and 30 g. The Obenge BMU fishers have experienced all the range of issues concerning cage fish farming including challenges associated with weak cage frames and faulty nets, cage breakage by wild animals to fish mortalities and harvesting. Originally, the cages were provided for by the Lake Basin Development Authority in conjunction with KMFRI. However, because they only have three cages, the farmers are now experimenting on fabricating their own cages from pipes and plastic materials in order to produce cages at an affordable rate. Similarly they have also tried to fabricate or sew their own cage nets (Only recently has it been possible to purchase nets in Kisumu from Monasa nets). To fend off wild animals, like hippos, they weld spokes around the cages.

From their experiences, these fish farmers use boats to stock, feed and harvest their fish. This way they avoid making piers which would make it easier for thieves to access them. So far these farmers have avoided using high input feeds and prefer naturally available food i.e. fish are never fed. Consequently, fish are stocked at lower densities of about 100 fingerlings m-3 leading to yields of between 14-16 kg m-3 at 150-200 g body weight in 4-6 months. Harvested fish are either sold or eaten by the members. The contact person at Obenge beach is Mr. Victor Mungu whose enthusiasm has made the group make strides in fish farming. Apart from cage farming, this group still depends to a large extent on the captured fish. It is only at a time when the cage culture venture has taken up and when each fisher person will have some few cages to boast of that they will eventually abandon fishing.

Conclusion

Cage fish culture in Lake Victoria basin has the potential to be beneficial and has attracted the attention of fishers and other members of the community. It can provide employment and additional income to local fishers and increase the supply of fish protein. Its main effect will be to reduce pressure on native fish by diverting fishers from fishing of wild stocks to aquaculture and thus provide alternative livelihoods. However like in other culture systems, there are several constraints which limit the expansion of cage culture. The principal constraint is a lack of suitable fingerlings to stock in cages. The supply of fingerlings is inadequate due to insufficient number of fish hatcheries, poor management of hatchery stocks and a tremendous increase in the demand for fingerlings for aquaculture throughout the region. Lack of inexpensive and suitable fish feeds is the other problem in cage culture especially because special diets that do not pollute the environment are necessary. Several measures are needed to expand and intensify cage culture in the Lake Victoria basin. Fish hatcheries should be established in or near the Lake Victoria basin to meet the increased demand for fingerlings from cage farms. These hatcheries should be supported by earthen ponds for nursing or on-growing of the small 0.5 g fingerlings up to the 20g size required to stock the cages. This has been practiced by Lake Harvest in Zimbabwe and is a common practice and occupation in Vietnam where some farmers specialise solely in on-growing of fingerlings from a hatchery to a larger 10-20 g size for cage sites. This way, farmers with fish nurseries are assured of a fairly quick turn-over and regular income since they keep the fingerlings for less than 3 months; hence less feed costs, and more profitability. At the same time, it is necessary for low-input environmentally non-polluting organic feeds to be availed for farmers at affordable prices. Further development of cage culture will also depend on additional limnological information such as changes in nutrients levels to ensure that adverse effects on the natural waters are minimized. As fish culture intensifies, the potential for disease is likely to increase. Therefore disease surveillance and control must be instituted in the cage culture programmes. Finally, training for farmers is required to impart the necessary know-how to enable efficient, sustainable and effective fish production from lake based cage culture.

Although caged fish can grow to larger sizes than pond raised fish, they are likely to face stiffer competition from capture fisheries at the local market because they are still far smaller than many of the wild caught stocks. Therefore, it is necessary that market strategies for caged fish are put in place, which include marketing caged fish distances away from the lake and value addition and processing leading to larger profits, covering all the fixed and variable costs, thus making cage culture a sustainable venture. As more fishers turn into farmers, it will be necessary for provision of more cage material, construction of cages and fish feed production. These could be motivating factors for industries to form in order to provide these services. Because fish feeds are still unavailable in Kenyan markets, farmers could start production of their own feeds. One major disadvantage of such feeds is that they are likely to be sinking. The Bomosa experience is that it is possible to produce semi-floating feeds locally, indicating a potential in establishment of an organic feed production industry targeting cage culture. The results of lake based cage culture trials indicate a relatively high growth of fish on natural lake productivity. Thus, cage culture as is practiced in Kenya can be economically and environmentally sustainable with proper cage culture production and marketing.

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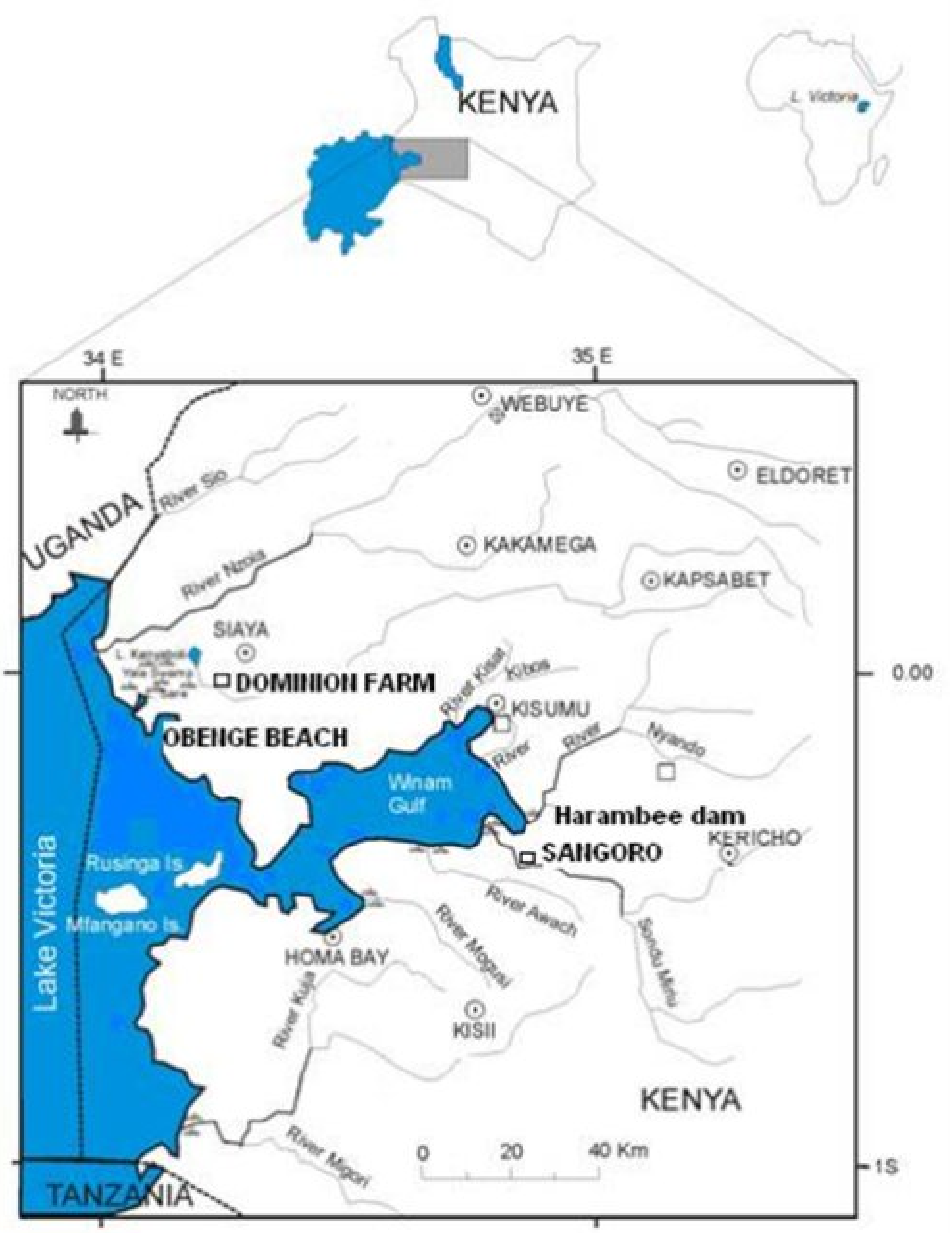
Organizations

Organization	Type of Organization	Organization Address	Contact Name	Web Address (URL)
Kenya Marine & Fisheries Research Institute	Research	KMFRI, P.O. Box 81651, Mombasa, Kenya director@kmfri.co.ke	Harrison Charo-Karisa	www.kmfri.co.ke
BOMOSA	Research Consortium	Moi University, PO Box 1125, Eldoret, Kenya d_liti@yahoo.co.uk	David Liti	http://bomosa.oeaw.ac.at/ or http://mu.ac.ke
Monasa Nets (Kenya) Limited	Equipment supplier	PO Box 9473, Kisumu, Kenya cabnibasa@swuftjusyny.cin	Miraly Nasrulah	

Links to Websites

Name	**Address (URL)**
BOMOSA	http://bomosa.oeaw.ac.at/
Kenya Marine & Fisheries Research Institute	http://www.kmfri.co.ke/
Lake Basin Development Authority	http://www.regional-dev.go.ke/lbda/index.htm
Moi University	http://www.mu.ac.ke/
Ministry of Fisheries Development, Kenya	http://www.fisheries.go.ke/
Egerton University	http://www.egerton.ac.ke/
NYADEC	http://nyadec.org/
Lake Harvest Aquaculture (Pvt) Ltd	http://www.lakeharvest.com/

Illustrations



Sites of cage culture in Lake Victoria region

Fingerling stocking of the unfed floating metal (aluminum) cages in Lake Victoria Obenge beach Kenya. Notice the spokes (white arrows) to keep hippos and other animals away (Picture by H. Charo)

Unfed floating cages in Lake Victoria, Obenge Beach, Kenya, showing the good water exchange. Notice the spokes for keeping wild animals away

Fishermen turned fish farmers improvising by making their own cage netting for tilapia cage culture

Easy to handle Bomosa cage at the Harambee Bomosa site in Nyando district on the shores of Lake Victoria, Kenya

A fish growth sampling exercise at Harambee Bomosa site- H. Charo-Karisa and J. Munguti lifting one of the cages to collect the fish, Munguti holding a fish, and the fish in a sampling basket

KMFRI Senior Scientist and program coordinator H. Charo-Karisa leads a team of KMFRI staff and fish farmers at Obenge beach in sampling fish from a cage, caged fish being removed from a cage for sampling and measuring length and weight of caged fish during sampling

Nyadec community celebrates a bumper harvest of fish, women trying their hand at scaling and Aquaculture Programme Coordinator KMFRI, H. Charo-Karisa sharing a point with EU Bomosa Project Coordinator D. Liti at Harambee Bomosa site - Michael Straif, Project manager looking on

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